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THE CAREER OF HERBERT SPENCER

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THAT "the evil that men do lives after them; the good is oft interred with their bones," is one of those literary palindromes which may be read both ways. Probably there is no great man, who, from the standpoint of pragmatism, has not done both evil and good, but the question as to which predominates can never be decided to the satisfaction of all. In the case of a Nero most men are agreed, but in that of a Napoleon opinions differ. Aside from war and politics there are few cases in which the consensus of opinion would fall on the side of evil, but many cases leave it doubtful, as, for example, those of Machiavelli, Hobbes and Rousseau, while in others it changes from one age to the next, as in the cases of Voltaire and Thomas Paine. Usually it is the evil that is most conspicuous during the life of the subject, and this has often been carried to the extreme of persecution during life and canonization after death. The world is full of monuments to those who were put to death for the things that are now chiefly admired. All this admonishes the biographer of the caution required in passing judgment on those of his own day and generation.

Herbert Spencer stands, and will probably always stand, on the light side of the picture, but there are very few of those familiar with his work who would maintain that there is no dark side. His Autobiography naturally presents the bright side, but the Life and Letters emphasize rather the shades than the lights, and it may be doubtful whether it would not have been better if that work had not appeared. Still, when we remember the deficiencies of human nature, perhaps this showing up of the whole man as he was is nothing more than a reassertion by him of the universally approved maxim of Terence: *homo sum.*

Leaving the world, then, to pronounce its judgment on this question of ethics, or pragmatism, let us briefly consider the career of Herbert Spencer in its broad outlines as brought out by his complete works supplemented by the four posthumous volumes now before us. There is certainly no vehicle in America, if there is any in the Old World, more appropriate to this task than the POPULAR SCIENCE MONTHLY. As has already been said by its present editor:

> Readers of this journal are familiar with Spencer's work, for he contributed to it nearly a hundred articles. It was indeed established by Dr. E. L. Youmans in 1872 largely with a view to provide a suitable medium for printing Spencer's "Study of Sociology," and . . . may be regarded as one of the by-products of his genius.[1]

As is well known, the first article in the POPULAR SCIENCE MONTHLY (May, 1872) is by Herbert Spencer: "The Study of Sociology, I., Our Need of It," which is also the first chapter of the book he was writing on "The Study of Sociology" for the International Scientific Series. In his "Autobiography" (Vol. II., pp. 284–286) he says:

> Before he left England my American friend [Dr. E. L. Youmans] volunteered to arrange for the carrying out of a suggestion which had arisen, I do not remember how, that the successive chapters of "The Study of Sociology"—the extra book in question—should be first published serially, in England and America at the same time. Here the *Contemporary Review* . . . was the contemplated medium; and a fit medium in the United States, Professor Youmans proposed to negotiate with as soon as possible after his return. . . . And now there arose an unlooked-for result from the understanding that had been made for simultaneous publication in America. Negotiations which Youmans had carried on with one or other periodical in the United States had all failed; and at the time when the first chapter had been put in type, neither he nor I saw how our plan was to be carried out. When the proof of this first chapter reached him it caused prompt and surprising action, as witness the following extract from a letter of his dated April 3, 1872:
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> "A thousand thanks for your favour of March 13th, with article on 'Study of Sociology' enclosed . . . You did wisely in sending it, and I decided upon our course in ten minutes after getting it. I determined to have a monthly at once, and in time to open with this article . . . We have started a monthly of 128 pages . . . I am utterly glad that things have taken the course they have. I have wanted a medium of speech that I can control, and now I shall have it."
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> The magazine thus started was *The Popular Science Monthly;* which, under the editorship of my friend, has had a prosperous career and done very good work.

Not only did the "Study of Sociology" thus all appear in the POPULAR SCIENCE MONTHLY, but Mr. Spencer continued to contribute to it chapters from his "Synthetic Philosophy" for many years, and declined to allow them to appear in other periodicals. When asked as

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[1] POPULAR SCIENCE MONTHLY, September, 1908, Vol. LXXIII., p. 285.

late as 1895 by the London editor of *McClure's Magazine* to contribute to that journal, he replied:

> I have, in virtue mainly of my indebtedness to my old friend for all he did on my behalf in the United States, felt bound to make the *Popular Science Monthly* my sole medium for publication of articles in the United States, and the obligation, which was preemptory during his life, remains strong after his death, since his brother occupies his place and he has continued his good offices on my behalf.[2]

The choice of a spokesman is less happy, but when we remember that the brothers Youmans, John Fiske, and most of the other disciples of Spencer in America have passed away, the difficulty in finding a proper person for such a task will be appreciated. Probably it should have fallen to an unqualified disciple who would simply pronounce an *éloge* in some extended form. The one to whom it has been assigned, while he yields to none in his high estimate of Spencer's talents and achievements, and has made this known on many occasions, has remained eclectic as to his peculiar doctrines, accepting such as appeal to him as sound, rejecting those which seem to be obviously unsound, and suspending judgment as to many that appear doubtful or await sufficient evidence.

In these several respects it is possible to classify Spencer's views under two heads and to explain the reasons which assign them to the one or the other class. The first class includes his cosmic philosophy in general, beginning with inorganic nature and extending through biology. It also includes much of his psychology, anthropology and sociology, considered in their philosophic aspects. The second class embraces his ethics as a whole, both individual and political. To it also belong most of the applications that he makes of psychology and sociology to current events, his dealings with the state, government, war, industry, business and economic problems. While no one will go so far as to say that his views on the first of these classes are always sound, or that those on the second are always unsound or questionable, it is still true that all that is great and profound in his philosophy belongs to the first of these classes, while his errors, his narrow views, and his unworthy utterances are confined to the second class.

And now as to the explanation of this. Primarily it rests on the fact that in treating the first class of subjects there was no room for the play of the emotions, while the subjects of the second class often appeal to the feelings, and Spencer, with all his logic and philosophic poise, never had his feelings under complete subjection to his reason. But secondarily, in the case of topics appealing to the feelings he unfortunately imbibed a whole series of prejudices during his early youth from which he was never able to free himself. Indeed, they were so

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[2] "Life and Letters," Vol. II., p. 89.

strong that he did not attempt to overcome them, but rather gloried in them to the end of his life. This, however, was not the worst consequence. They blinded him to everything that was taking place in the world around him, to the extent that social movements, which, could he have seen it, were the natural outcome of the cosmical principles he had laid down, were regarded by him as the signs and omens of social degeneracy and as portending a relapse into barbarism. In the inorganic and organic worlds he had not been taught anything, and his vast intellect was free to enter those fields and work out far-reaching principles untrammeled by early prejudices. In the ethical, political, and economic worlds he was enclosed in a shell and could grow no larger than his prison walls. To use one of those biological analogies of which he was so fond, in the physical and organic sciences he was a vertebrate with an adjustable internal skeleton, while in the moral and political sciences he was a crustacean without the power to shed his carapace.

In appraising Spencer's truly great contributions to human thought and knowledge we are therefore compelled to leave out of view all his earlier writings, except perhaps an occasional essay. His letters on the "Proper Sphere of Government" (1842), his "Social Statics" (1850), his "Principles of Psychology" (1855), his "Education" (1861), are all excluded from this high meed of praise. The same is true of Part I. of his "First Principles" (1862), which formed the stumbling-block to his whole system of philosophy, and if published at all, should have been placed at the end as a sort of appendix or curious metaphysical by-product. Solid ground is reached only in Part II. of the "First Principles," and in only one other of his works is his master mind revealed with equal clearness. His grasp here of cosmical principles is astonishing, and the vast swing of his logic carries the reader irresistibly on, sweeping majestically across the whole cosmos in many different directions, until everything is compassed in a universal scheme. Here, too, more than anywhere else, is his happy choice of expressions, never before employed, but precisely and concisely characterizing cosmical principles, singularly manifest. The word "evolution" itself, which perhaps he was the first to use in a philosophic sense,[3] though introduced in his earlier works, is here given its full meaning, and the thought it conveys has now captured the world. The phrase "redistribution of matter and motion" sums up the cosmic process as it had never been summed up by any other phrase. The assertion that evolution proceeds "from the homogeneous to the heterogeneous" has never been questioned except by those who give different meanings to the terms from those intended by Spencer, and which are the proper and even the popular meanings. Such phrases as "the

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[3] "Life and Letters," Vol. II., p. 329.

instability of the homogeneous," "the rhythm of motion," "the multiplication of effects," and such single terms as "aggregation," "segregation," "equilibration," "dissolution," are all fraught with profound significance, and most of the processes described by them take place in all departments of nature. The introduction and illustration of these terms and the description of the processes of nature of which they are the names, would alone make "First Principles" an immortal work.

It is true that Spencer failed to see the essential distinction between cosmic and organic evolution, and when it was pointed out in 1877,[4] as it was not his own idea, he characteristically ignored it. He also missed the principles of creative synthesis, cosmic, organic and social synergy and sympodial development, which are quite as important as those set forth in "First Principles." But he is to be judged for what he did rather than by what he did not do. There is, however, one omission, which, deliberate and intentional though it was, has not been condoned by his readers. This is his failure to elaborate these fundamental principles of inorganic nature in a manner proportionate to that in which he elaborated the principles of biology, psychology, sociology and ethics. Uniform regret has been expressed by his readers, including his warmest admirers, that he should have abandoned this great work so auspiciously begun, and hurried on to the more special and complex sciences before laying an adequate foundation for them. The present writer was among those to express this regret and to maintain that his excuse for omitting the two volumes upon which the "Synthetic Philosophy" would and should have rested, viz., that the scheme would have been too extensive for him to complete it, and that "the interpretation of Organic Nature after the proposed method is of more immediate importance," was not a sufficient or valid excuse. It is generally felt that if these two volumes had been written, which might have borne the title of "Principles of Cosmology," it would be small matter whether the "Principles of Ethics" ever saw the light or not.

The world was even left in the dark as to how and in what order he would have treated inorganic nature had he written the omitted volumes. It is true that in the opening paragraph of the first volume of the "Principles of Sociology" he says:

> Of the three broadly-distinguished kinds of Evolution, we come now to the third. The first kind, Inorganic Evolution, which, had it been dealt with, would have occupied two volumes, one dealing with Astrogeny and the other with Geogeny, was passed over because it seemed undesirable to postpone the more important applications of the doctrine for the purpose of elaborating those less important applications which logically precede them.

The bare names, therefore, which he would have given to the two

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[4] POPULAR SCIENCE MONTHLY, October, 1877, Vol. XI., pp. 672–682.

volumes were thus made known, but from them it was impossible more than to conjecture what the treatment would have been. The complete scheme was drawn up early in 1858 and sent to his father in a letter, but the revised scheme, issued in 1860, and with which we are all familiar, wants the details for all below the biology. Not until the "Autobiography" appeared in 1904 was this hiatus supplied.[5] This was the reason for publishing a letter from him dated September 19, 1895, in which considerable was said on this subject. Nearly eight years, however, were allowed to elapse before this step was taken in 1903. His permission to publish it would have been asked had it not been known that at that date Mr. Spencer was nearing his end, his death occurring in December of the same year, and it seemed highly important that information so vital to his system should not be lost.[6]

While, therefore, Mr. Spencer's treatment of inorganic nature, so far as it could be judged from "First Principles" and other indications, was full of promise, still, inasmuch as he did not fulfil that promise by an exhaustive elaboration of it, it was soon overshadowed by his work in the next great field, that of biology, the only other field of his labors in which no early preconceptions existed to warp his judgment or impede the flight of his genius.

Herbert Spencer's "Principles of Biology" is the gem of his "Synthetic Philosophy," and must rank for all time as his masterpiece. In it he founds the science of biology squarely upon that of organic chemistry, and "Chemical Development" was to have been the final topic of "The Principles of Geogeny."[7] This makes clear the filiation of the sciences thus far. Then come his several proximate definitions of life, closing with "the broadest and most complete" one: "the continuous adjustment of internal relations to external relations." Few have been satisfied with this, and the more it is studied the less it seems to fulfil the conditions. The objection to it is that there is no life in the definition. It is strange that he should have failed to cement the lowest organic science, biology, to the highest inorganic science, chemistry, by recognizing the brief step from the spontaneous molecular activities of the most complex organic compounds, the albuminoids, to the no more spontaneous molar activities (motility) of the simplest living substance, which we know as protoplasm, and believe to result from the further recompounding of the former.[8]

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[5] "Autobiography," Vol. II., p. 17; "Life and Letters," Vol. II., pp. 158–159.

[6] "Pure Sociology," pp. 66–67. A portion of this letter appears in "Life and Letters," Vol. II., pp. 90–91. Mr. Duncan should have mentioned this earlier publication of the letter in full followed by the reply to it and a further discussion of the principles involved.

[7] "Life and Letters," Vol. II., p. 159.

[8] *Cf.* "The Organic Compounds in their Relations to Life," *Proc. A. A. A. S.*, Vol. XXXI., pp. 493–494; *The American Naturalist*, Vol. XVI., December, 1882, pp. 968–979.

But this fundamental criticism aside, Spencer's handling of biological problems is nothing short of masterful. In his chapters on growth, development, function, adaptation, generation ("genesis"), heredity, variation, etc., although not a specialist in any branch of biology, he marshals an immense body of facts in support of fundamental principles, many of which had never before been discovered. In dealing with heredity he postulates the existence of "physiological units," later changed to "constitutional units." The "Principles of Biology" was published in 1864, and therefore Spencer could have known nothing of Darwin's "pangenesis," treated in his "Variations of Animals and Plants under Domestication," which appeared in 1868. But Spencer's "physiological units," as he points out,[10] are not at all the same as Darwin's "gemmules." They are still less similar to Weismann's "biophores."[11] They are nothing but "compound molecules (as much above those of albumen in complexity as those of albumen are above the simplest compounds," and are for the same organism "substantially of one kind." Why he did not admit that they are merely forms of protoplasm we do not know, but certain it is that biologists are now coming to believe that no hereditary units in the sense of independent bodies exist, and that all the phenomena of heredity, obscure and recondite as they are, can be as easily conceived to result from the action of protoplasm in various ways not yet fully understood, as from any imaginary bearers of hereditary "Anlagen."[12]

It is in Part III. on the "Evolution of Life" that the philosopher comes forth in his full power. After disposing of the special creation hypothesis, he attacks the cosmic principles underlying the organic world. Many of those enumerated in "First Principles" are shown to be in full force on the biotic plane. The process from homogeneity to heterogeneity finds its clearest exemplifications here, and the two great principles of differentiation and integration are formulated and illustrated with wonderful force. We can not here even enumerate all the biological principles set forth in this work, but the application of the principle of equilibration to the organic world can not be passed over in silence. The Lamarckian principle of increase by use and atrophy from disuse, called somewhere by Spencer "use-inheritance," and early recognized by him as "the inheritance of functionally-acquired modifications," now becomes, in the new terminology of biology, "direct equilibration," while natural selection, which Spencer, along with many others mentioned by Darwin in the later editions of the "Origin of Species," had foreshadowed before that work appeared,

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[10] "Life and Letters," Vol. I., p. 199.

[11] *Ibid.*, Vol. II., p. 52.

[12] *Cf.* Minot, "The Problem of Age, Growth, and Death," New York, 1908, pp. 233 ff.

becomes "indirect equilibration." The discussion of these two principles is among the most profound of all of Spencer's writings. The subject, so intimately connected with this, of the transmission of acquired characters, was not overlooked in the "Principles of Biology," but it was not brought into the foreground until Weismann's "Essays" began to appear, denying its possibility. Spencer, as is known, entered the lists with his paper on "The Factors of Organic Evolution," and continued to reply to Weismann for a number of years. In him the trained biological specialist found a foeman worthy of his steel. Readers of these papers on both sides will of course differ in their judgments on the argument according to their cast of mind, but all will admit that Spencer's presentation of the case was able, and to it, as much as to anything else, were due the many notable concessions that Weismann was from time to time compelled to make.[13]

In the second volume of the "Principles of Biology," devoted mainly to morphology and physiology, Spencer showed that he could play the rôle of a specialist, but his special studies and illustrations all have a philosophic purpose in establishing principles. These, however, belong for the most part to the minor or more special laws of biology, and do not call out the same philosophic powers as the major and more general laws dealt with in the first volume. Perhaps the most important of these laws is what he calls the "antagonism between growth and sexual genesis," which might otherwise be stated as the law that nutrition and reproduction are inversely proportional. The truth of this is known to practical breeders, florists and horticulturists, but not to the general public, and it has some interesting results.

Spencer lived to revise his "Biology" and introduce into it much of the Weismann controversy and other features which had not presented themselves clearly at the time the work was originally written. Upon the whole it is a remarkable work. Surprise has often been expressed that trained specialists in biology had rarely or never been able to trip him on any of his statements. This is partly explainable by the fact that Professor Huxley read the proof of a considerable part of the work, but it does not appear that he found much to correct, and we must admit that Spencer possessed a remarkable faculty of accurately stating biological facts that he had not himself observed, and a still greater talent for correlating and interpreting them and fitting them into his universal scheme.

Let us now turn to the "Principles of Psychology." In his "Synthetic Philosophy" Spencer placed it after the Principles of Biology. Although he says little about his reasons for this arrangement, it seems clear that he regarded it as the order of evolution. Yet

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[13] *Cf.* Weismann's "Concessions," Popular Science Monthly, Vol. XLV., June, 1894, pp. 175–184.

in his attacks on Comte's serial classification of the sciences he denies that there is any serial order.[14] But whenever he mentions the subjects of his "Synthetic Philosophy" he always arranges them in the same order,[15] corresponding to that of his original program and of all subsequent programs. No one will probably question the propriety of this arrangement, and it may be inferred that he regarded psychology as having some such relation to biology as the latter has to chemistry, *i. e.*, as in a sense growing out of it. Now, whereas he does clearly show this filiation of biology and chemistry, it is difficult to find in his psychology a recognition of its dependence upon biology in the same sense. This is probably due to the fact that the "Psychology" was first written and published as an independent work several years before he conceived the idea of a "Synthetic Philosophy," and afterward revised, enlarged, and adapted, and then set up in its proper niche in the general structure. But the task of adapting it was not an easy one, and he seems to have devoted himself more to what he regarded as its improvement, to the answering of criticisms, and to bringing it up to date, than to linking it on to his "Biology" which stands before it, and to his "Sociology," which was to follow.

He wrote the "Psychology" when fresh from the reading of Hamilton, Mansel, Mill and Kant, and the point of view was that of the old philosophy of mind, which he, indeed, attacked, but scarcely from the modern scientific point of view. This is more true of the second volume than of the first. The work opens, as do most works on psychology, with a treatise on the nervous system, and the chapter on Æstho-physiology is certainly luminous and forms a new departure. His definition of mind as consisting of feelings and the relations between feelings is inexpugnable. In part III. he treats of life and mind as "correspondence," but does not seem to regard mind as an outgrowth of life. In treating pleasures and pains at the end of part II, he recognizes the existence of feelings which do not consist of pleasure or pain, and even calls them "indifferent," but he does not there or elsewhere show that the function of such feelings is to furnish knowledge. This was perceived by Reid, though he did not grasp its import. Spencer thus fails to show the genesis of the rational powers. He clearly sets forth the biologic origin of feeling, but he does not perceive that the intellect was also an advantageous attribute whose origin can be explained on natural principles. Notwithstanding the acknowledged ability of this work, these and other deficiencies deprive it of the title given it by some of being Mr. Spencer's *chef d'œuvre*. Standing as it does between the "Biology" and the "Sociology," with neither of

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[14] "Life and Letters," Vol. I., p. 97; "Pure Sociology," p. 66 (this part of his letter is omitted in the "Life and Letters," Vol. II., p. 90.

[15] "Life and Letters," Vol. II., pp. 285, 328.

which it is adequately linked, it seems isolated and solitary. The failure clearly to affiliate mind upon life is not its worst fault. From the standpoint of the sociologist the most glaring defect is the absence of all recognition of the psychologic basis of social phenomena. Neither in the "Psychology" nor in the "Sociology" which follows is there to be found any attempt to show what are the underlying causes of social phenomena. The nature of social energy which moves the world is nowhere set forth, the distinct rôles played by feeling and thought, as the motor and rector[16] agencies of both the individual and society are not recognized, and both psychology and sociology are thus reduced to mere descriptive sciences. Much the same may be said of his failure to recognize a vital energy in biology with motility as the dynamic agent, which also leaves biology in the descriptive stage. Life and mind are forces, and organic, psychic and social structures are magazines of energy. Any system that fails to recognize this is not a full-fledged science.

It may be said that Spencer constantly insisted that it was feeling and not ideas that moved the world, as opposed to Comte's statement that ideas govern or overthrow the world. It is clear that he misunderstood Comte, who held the same view as Spencer, and that the two statements are not antagonistic.[17] Spencer also said that "the will is a product of predominant desires to which the reason serves merely as an eye."[18] This is very true, and Schopenhauer had said it forty years before him. But such scintillations of the truth do not make a science nor justify us in saying that he thereby furnished sociology with a psychologic basis.

Coming now to the "Principles of Sociology," we find that the work was not hampered by any previous work, and, as in the "Biology," the field was clear for a new start in a most alluring direction. If the order in which the volumes of the "Synthelic Philosophy" stand is the order of nature, marking the course of evolution, we should expect to find the "Sociology" opening with a chapter or an introductory part setting forth the causal connection between sociology and psychology. But, just as no causal connection was shown between biology and psychology, so none appears binding psychology and sociology together. This confirms what was said of the isolated condition of the "Principles of Psychology." What we do find, however, is a rather definite intimation that it is biology rather than psychology that forms the natural basis of sociology. How could any one be expected to doubt this when nothing is said in the first volume of the "Sociology" about its relation to psychology, while, after the long treatise on the beliefs,

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[16] Used by Fourier in this sense ("*moteur et recteur*").

[17] *Cf.* Applied Sociology, pp. 41–43.

[18] *Westminster Review*, January 1, 1860, p. 93.

customs, and ideas of primitive races, belonging rather to anthropology, we find in part II. that "a society is an organism," and that social growth, social structures, social functions and social organs are treated from the strictly biological point of view? Mr. Spencer denied that he based sociology upon biology and censured two American authors for intimating that he seemed to do so, but the comparison that he used is not at all apposite.[19]

The other two volumes of the "Principles of Sociology," based as they are on his great compilation, "Descriptive Sociology," are above criticism in their comprehensive sweep as a vast induction. Some of his facts will, of course, be denied, but he admitted that the reports of travelers must be taken with many grains of allowance. Yet these are almost the only sources from which an author who is not himself a traveler must rely. For those therefore who consider such a work to constitute "Sociology" the only vulnerable part is the terminology, classification, and arrangement of the subject-matter. The phrase "ecclesiastical institutions" may be justly objected to as seeming to predicate something like a church of the religious structures of primitive man. The word "ecclesiastical" might be stretched sufficiently to justify this were there no better term, but it is universally admitted that the priesthood was practically coeval with human society, and we possess an adjective corresponding to this noun which is more euphonious and more expressive than the one used. By all means, then, should the phrase *sacerdotal institutions* be substituted for "ecclesiastical institutions." The introduction of "political institutions" between the "ceremonial" and the sacerdotal is a forced arrangement. The ceremonial are largely sacerdotal, and their separation is difficult. The sacerdotal should probably stand first, and the "professional," beginning with the "medicine man," so similar to a priest, should follow. "Political institutions" would then be in order, to be followed by "industrial institutions." But Mr. Spencer had no conception of gentile society and the fundamental distinction between it and political society, so clearly set forth by Morgan. This classification shows how late the latter class of institutions have always been in the historical development of society. Still less was he acquainted with that other most important of all transformations which is undergone by every advanced society at the proper stage in its history, viz., union and amalgamation of groups, whether through war or peace, by which a third and higher group results from the blending of two lower groups, constituting what is appropriately called the cross-fertilization of cultures. It is only through this that all the higher political, industrial, economic, and professional institutions arise.

After thus threading the mazes of cosmic, organic, psychic and

[19] "Life and Letters," Vol. II., p. 357.

social phenomena, we come at last to the "Principles of Ethics," which Mr. Spencer regarded as the crown of his system. One can not but be struck by the resemblance in this respect of Herbert Spencer's career to that of Auguste Comte. Both began with a lively interest in what may be called political ethics, an interest which they both continued to feel through life. But both saw, after their early survey of the field, that the world was not ready for their final achievement, and therefore both stopped and devoted twelve or fifteen years of arduous labor to laying a scientific foundation for the *magnum opus* which was to reform the world. Comte laid special stress on this, and placed as a motto at the head of the first volume of his "Politique Positive" the lines of Alfred de Vigny:

Qu'est-ce qu'une grande vie?
Une pensée de la jeunesse, exécutée par l'âge mûr.

Spencer could not even wait to complete the last of the preparatory works, and stopped in the middle of it to write the final work. So strongly was he impressed by the importance of this last work, and so apprehensive that he might not live to complete it, that he said in the preface to the first part ("Data of Ethics" issued separately):

> I am the more anxious to indicate in outline, if I can not complete, this final work, because the establishment of rules of right conduct on a scientific basis is a pressing need. Now that moral injunctions are losing the authority given by their supposed sacred origin, the secularization of morals is becoming imperative. Few things can happen more disastrous than the decay and death of a regulative system no longer fit, before another and fitter regulative system has grown up to replace it.

The implication of course is that Herbert Spencer's "Principles of Ethics" will henceforth constitute the Koran of moral doctrine to the exclusion of all other codes! Comte has been pronounced an egotist and a fanatic for proclaiming himself the high priest of the religion of humanity, but he never assumed to be an infallible pope in the domain of moral conduct. The parallelism, however, does not end here. The world has passed judgment upon Comte's career, and while his final work for which he had lived and labored, viz., his "Positive Polity," has been declared a mistaken dream, the preparatory work, his "Positive Philosophy," which he intended to be only the pedestal upon which the monument was to stand, is looked upon by most men as a path-breaking, by many as an epoch-making achievement, and as marking the beginning of scientific philosophy. In Spencer's case it is too early to speak thus definitely, but all things point to the complete rejection of his political ethics as outlined in "Social Statics" and perfected in his "Principles of Ethics" and "Man Versus the State," while his cosmic philosophy, which he regarded as little more than a foundation for the other, grows more solid with time, and is clearly seen to be too massive for the flimsy superstructure that he sought to erect upon it.

In Spencer's system ethics is placed last in the series of subjects or sciences, as if it were the highest evolutionary product. Although he laid no stress on the serial arrangement of the sciences, and in his little book on the "Classification of the Sciences," written to refute Comte's "hierarchy," he practically ignores it, still he could not answer the charge of arranging his volumes in practically the same order as Comte arranged the sciences. Nor did he deny that he regarded this as the order of evolution. As Comte did the same for his "Morale," the implication is that they both regarded ethics as a science of the same type as the others, only higher in the scale, and, in fact, the highest of them all. It would thus grow out of and be affiliated upon sociology. The treatment of it does not in either case sustain this claim. In Spencer's case this is much more marked than in Comte's, because they had quite different ideas of what constitutes a moral science. Spencer, as we have seen, regarded it simply as a "regulative system," which is not a science at all. His treatment of it virtually carries out this idea, and his "Principles of Ethics" scarcely differs from the traditional moral teaching of other writers, except that it is "secular" and recognizes no religious or "ultra-rational" sanction. After he had abandoned his "absolute ethics," as set forth in his "Social Statics" (expunged from the last edition), but shown to be false by a study of the widely divergent moral ideas of the races of men, the last claim to the title of a science had been withdrawn from ethics, and it stood at the head of the system having no organic connection with the other sciences of that system. What, then, is his ethics? It is simply an attempt to make a practical application of the true sciences, especially of sociology to human needs. In so far as it is a science in any sense, it is an applied science, and the greater part of it may be denominated applied sociology.[20]

The subject of Spencer's relations with Comte and the similarity of their ideas has been purposely avoided in this article, because it presents the least attractive side of a great man's mind. His overweening affection for what he called "the progeny of the brain,"[21] his intense love of originality, which often seems to exceed his love of truth, and his morbid sensitiveness to any apparent appropriation of his ideas, blinded him to the merits of others and often led him to refine upon a distinction without a difference. Jealousy as well as envy may be a compliment. This can alone explain Spencer's attitude toward Comte. He must have felt, and been oppressed by the fact,

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[20] *Cf.* "Applied Sociology," pp. 317–318.

[21] "Life and Letters," Vol. I., p. 254.

that there was a man on the other side of the Channel who, like himself, was striving to give the world a philosophy of science. And in fact, from this point of view, Auguste Comte was to the first half of the nineteenth century what Herbert Spencer was to the second half.

A fuller discussion of the merits and demerits of Spencer's political ethics is also purposely avoided in this place, partly for want of space, partly because it would have to be too critical for the appraisement here proposed, and partly because it has already been attempted, not only by others but by the present writer.[22]

The statement has been so frequently made that Mr. Spencer's sociology and his political and economic doctrines do not logically follow from his law of cosmic and organic evolution, that something more might naturally be expected here on that point than has been said above as incidental to the discussion of other questions. This subject is, however, too large to be treated here, and would require a separate article. This lack has been partially supplied in other places and to these sources the reader is referred.[23]

[22] "The Political Ethics of Herbert Spencer," *Annals of the American Academy of Political and Social Science*, Vol. IV., January, 1894, pp. 582–619. Publications of the Academy, No. 111.

[23] "Herbert Spencer's Sociology," *The Independent*, New York, March 31, 1904, Vol. LVI., pp. 730–734; Herbert Spencer's Autobiography, *Science*, N. S., June 10, 1904, Vol. XIX., pp. 873–879; "The Sociology of Political Parties," *American Journal of Sociology*, January, 1908, Vol. XIII., pp. 439–454.

LINEAMENTS OF THE DESERT

By Dr. CHARLES R. KEYES
DES MOINES, IA.

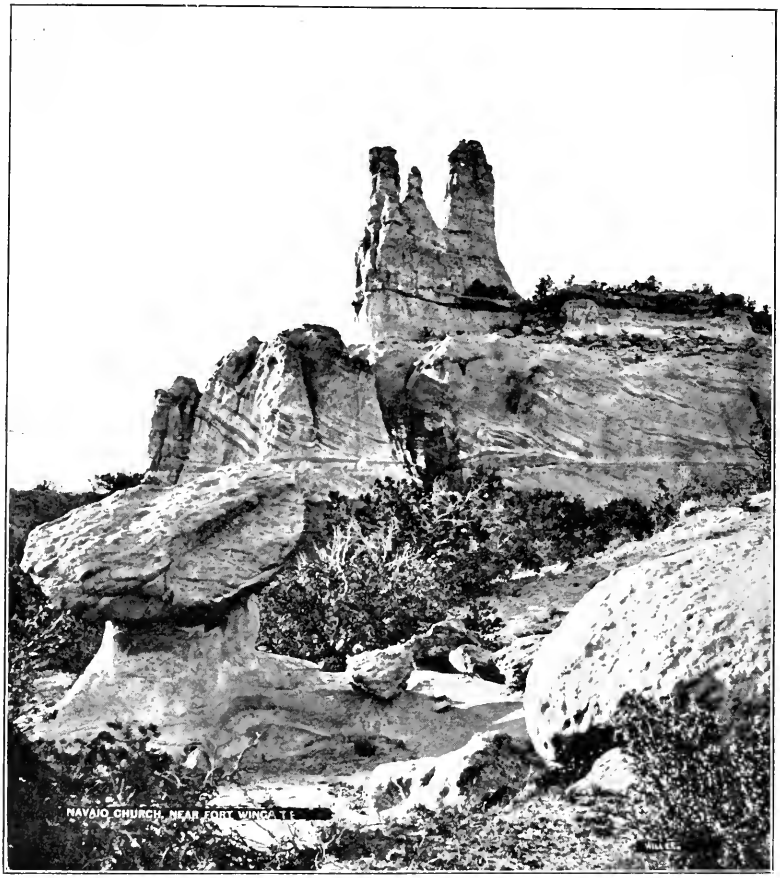
OUR notions of the genesis of desert landscapes have lately undergone complete revision. In land-sculpturing under conditions of aridity we are led to recognize some entirely new phases of geologic operations. The principles deduced are not alone applicable to countries with excessively dry climates, but likewise to all lands of the earth.

In the moister regions of the globe, or those parts with which the majority of us are most familiar, moving water is so universally regarded as the chief agent of denudation that other erosive means are seldom more than barely considered. In the arid districts there is a reversal of the relative efficiencies of the erosion processes. Water-action is of quite secondary consequence. Wind-scour, or deflation, is not only the most vigorous, but often almost the sole, erosive power.

The tremendous efficiency of wind as an erosive agent has been lately brought to general notice mainly through the results of Passarge's investigations in the South African deserts. His principal deduction is far-reaching in its scope and significance, and seems destined to stand in geology as one of the grand generalizations of the new century. In our own country it opens up vast and fertile fields of geologic inquiry.

The desert regions of earth have given to modern geography its most suggestive and fundamental concepts. This is a fact that is all but forgotten by most of us who are accustomed daily to apply these basic principles in the more familiar moist tracts in which we live. Yet the definite cycle of evolution which land-forms pass through, the base-level to which all erosion tends, and a general plains-leveling, without regard to sea-level, that goes on in dry countries, are deductions of the desert.

True desert conditions prevail over a much larger proportion of our earth than most of us appreciate. Southwestern United States, the greater part of central Mexico, western South America, South Africa, northern Africa, southwestern, central and east-central Asia, eastern Europe and central Australia, all present vast areas of territory which have rain-fall insufficient to raise ordinary grain crops without artificial watering. The desert, however, is not the repulsive land that its name whenever mentioned suggests to the layman. Most of it is not



NAVAJO CHURCH, NEW MEXICO. Ponderous pinnacles of eolian erosion, rising nearly a thousand feet above the valley at left. (C. E. Dutton, photo.)

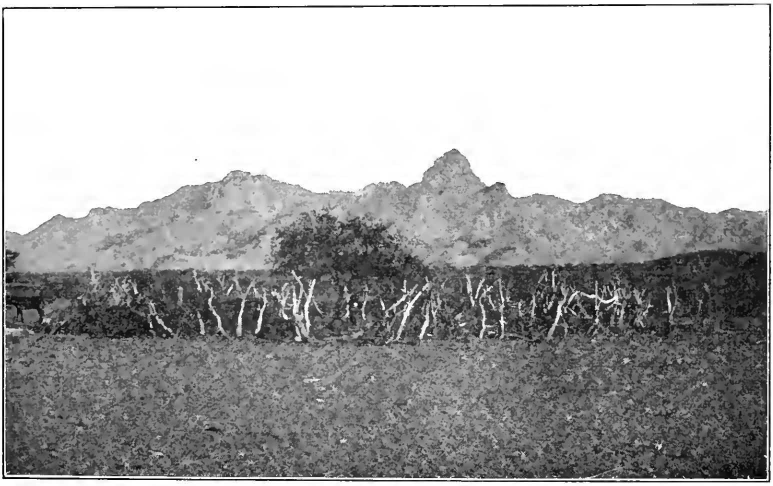
the barren waste of popular fancy. Vast tracts of it are certain to be reclaimed to the uses of mankind. Some of it is doubtless to become the most eagerly sought of all estates. Its beauties and its treasures are only beginning to be understood. Even scientists have only commenced to turn their attention seriously to the make-up, features and resources of the so-called desert regions.

The idea of a base-level of erosion, lying but slightly above tide, but below which stream-corrasion can not go, has done for geography what the principle of evolution has accomplished for biology. It is, in fact, the evolutionary principle applied to land sculpture. This theory of Powell's is justly regarded as one of the three grand deductions which geology of the century just past has bequeathed to science. Conceived midst the arid regions of the West, its widest influence has been in the moister countries of the earth.

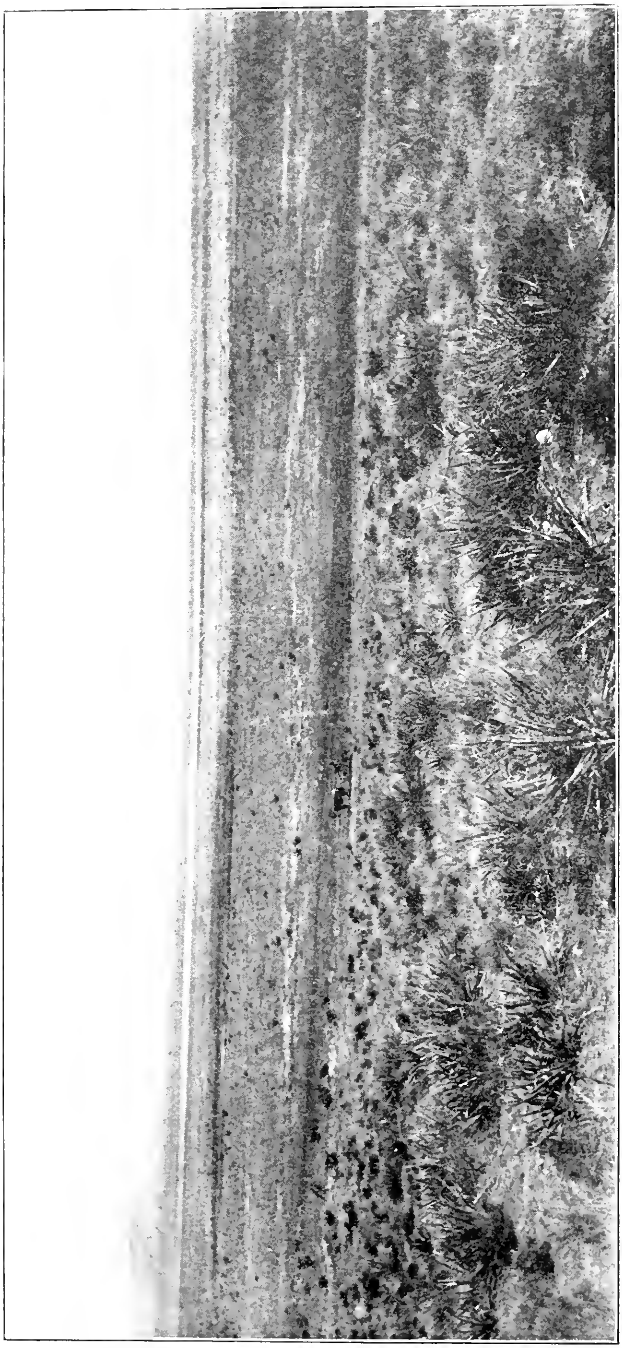
The second great geographic principle, that of the verity of a distinctly staged cycle of erosion comparable in a way to the periods of growth in the human individual, has done more than anything else to advance and place the study of geography on a truly genetic basis. It is to Davis we are chiefly indebted for devising for us a practical working scheme.

What the base-level of erosion is to the general theory of land degradation under conditions of a normal moist climate Passarge's great deduction of the possibility of general land leveling and lowering without regard to sea-level is to land sculpture under conditions of a dry climate. Until within the last lustrum the lineaments of the great desert regions of our globe have remained without adequate or satisfactory explanation. The genesis of the grander features of the landscape on the basis of ordinary tectonics, or of normal erosion during former wet climatic periods, or of water-action under present conditions, has always met with seemingly unsurmountable obstacles. The origin of the salient features of the desert, its peculiar mountains, its smooth plains, its strange plateaus, its streamless surface, its remarkable rock-floor, and its many other unexpected features, are only beginning to be fully appreciated in their proper relationships. To us of the moister countries they present many novelties. They make us acquainted with the vigorous workings of geologic processes to which we are as yet almost complete strangers.

In the operations of the geologic processes under conditions of an arid climate the most noteworthy effects as compared with those under normal conditions are the prevalency, the constancy and efficiency of



GHOST-LIKE DESERT RANGE OF BABOQUIVARI, ARIZONA. Central Peak is nearly a mile high and ten miles distant. (W J McGee, photo.)



PLAIN OF JORNADA DEL MUERTO, NEW MEXICO. A typical intermont plain of the desert. Mountain rim in background at left is 30 miles distant; that on the right 75 miles.

wind-scouring, the very subordinate, local and sporadic character of water-action, and the remarkable plains-forming tendency which deflative erosion effects.

Since most of our conceptions of landscape genesis are derived from our experiences in a normal moist or wet climate, the erosion agency with which we are best acquainted is running water. In the desert regions actually and necessarily water plays but small part in erosion. With less than ten inches of annual rainfall, most of which sinks into the earth as soon as it touches it, as in the dry regions of southwestern United States and the northern part of the Mexican tableland, or less than one inch as in the Nubian and Libian deserts of north Africa, the erosive influences of water must be all but a negligible quantity.

With water-action reduced to relative impotency in the desert region, wind-scour assumes a rôle the denuding power of which has been heretofore little considered. Its action is general and constant. Its effects are probably even more vigorous than the work of water under normal climatic conditions. In the effort to reduce the land surface to a low-lying plain the belts of hard and soft rocks are brought into somewhat stronger contrast than in the case when water is the chief agency of planation. The geologic structures are more sharply accentuated. The rock-floors are cleaner swept. The belts of weak rocks are faster removed. At all times the plain is more characteristically the main relief feature.

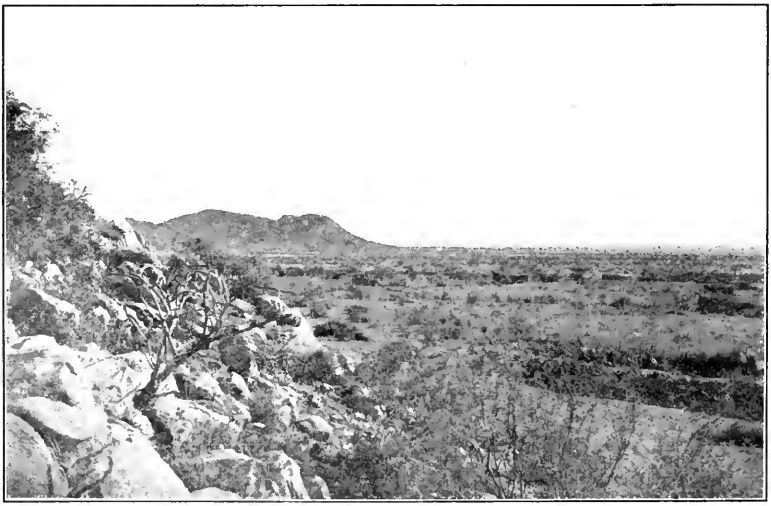
Contrary to popular belief the great desert tracts of the earth are mountainous regions. The mountain character has many novel and instructive peculiarities. Yet so dominant is the plains feature locally that the mountain ranges, bold and lofty as they often are, rise sharply from the level expanse as do volcanic isles out of the sea. So characteristic is this aspect that it is, in the South African deserts, appropriately denominated the "Inselgeberglandschaft."

In regard to the manner of their development the salient lineaments of the desert deserve much more attention than ever has been given them. They acquire new meanings when their peculiarities are considered in the light of an origin eolian in nature. Notwithstanding the fact that some of us, whose lifelong experiences have been mainly with the workings of the geologic processes in the moister parts of the globe, may find it a little difficult to fully appreciate at first the direct significance of many of the details of the relief features, a visit to the desert soon convinces us of their verity. There are at least a score of these physiographic characteristics of the dry lands that are especially striking.

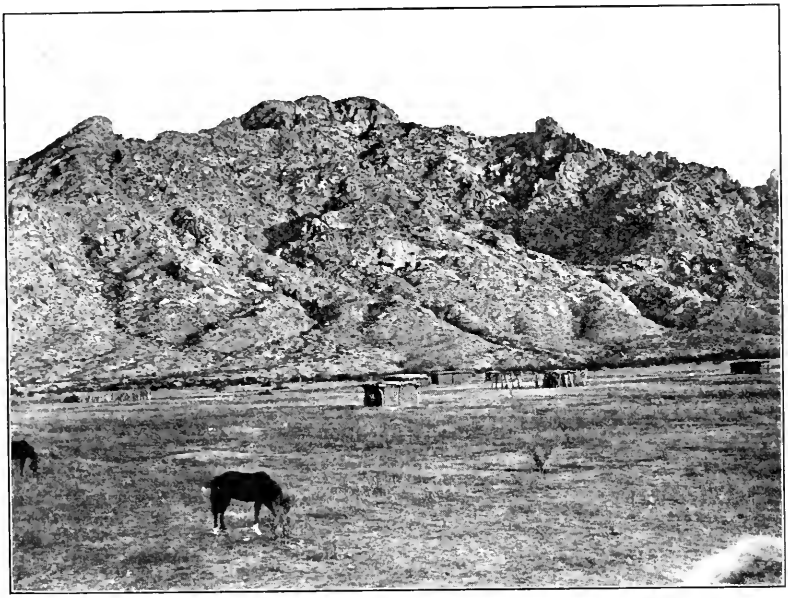
The dominant feature of such desert regions as the western part of our own country and of Mexico is the interrupted plain the general surface of which is 5,000 to 7,000 feet above the sea. Out of it rise abruptly the numerous mountain ranges to like heights above the plains-surface. Of this region four fifths are plain; one fifth highland. The vastness and evenness of the intermont plains is a matter of much speculation with all who travel the region, scientist and layman alike. Extensive desiccated lake-bottoms they are usually regarded. They are sometimes considered to be intermont basins deeply filled with wash from the peripheral highlands. At the present time the only adequate explanation of their physiognomy is that they are fashioned mainly by eolian agencies with some slight modification by water.

The complete isolation of the different mountains is one of the most remarkable facts concerning the desert features. In most parts of the world there is some more or less close structural relationship between neighboring mountains which are often united to one another by foot-hills. In the desert there is no such tectonic connection. The mountain ranges are all independent individuals without relationship of any kind to one another. Structural mountains, volcanic mountains, laccolithic mountains, fault-block mountains and high residual plateau mountains are neighbors distinctly separated by stretches of level plain.

Mountain ranges throughout the dry regions of western America are completely and evenly surrounded by level plains as if by the sea. They are numerous, short and narrow. Upon the map Dutton has likened them to an army of caterpillars crawling northward out of Mexico, dividing as it enters the United States, the main body turning



GREAT POSO VERDE PLAIN. Isolation of the mountains, sharp meeting of plain and mountain, and absence of foothills are noteworthy characteristics.
(W J McGee, photo.)



Coyote Mountain, Arizona, rising 3,000 feet above the plain. Devoid of soil; impotency of water-action shown in the small volume of fans at the base.

westward and then northward again until it passes into the British possessions. The simile is as striking as it is apt.

To the average mountaineer, one of the strangest characteristics of the desert ranges is the absence of foot-hills. The main eminences of the mountains rise directly from the plains. The line where plain and mountain meet is as sharply defined as if drawn with a pen. Often this line is represented by high mural faces that can be scaled at but few points. For this reason it is, chiefly, that the mountains appear to be half buried by the drifting sands. It is on this account largely that the plains areas appear to be leveled by the waters of former seas, of which the mountains formed the coastal cliffs. The illusion is all but completed by the fact that the phenomenon is perfectly independent of geologic structure. This surprising feature is really one of the most novel peculiarities of eolian action under conditions of aridity.

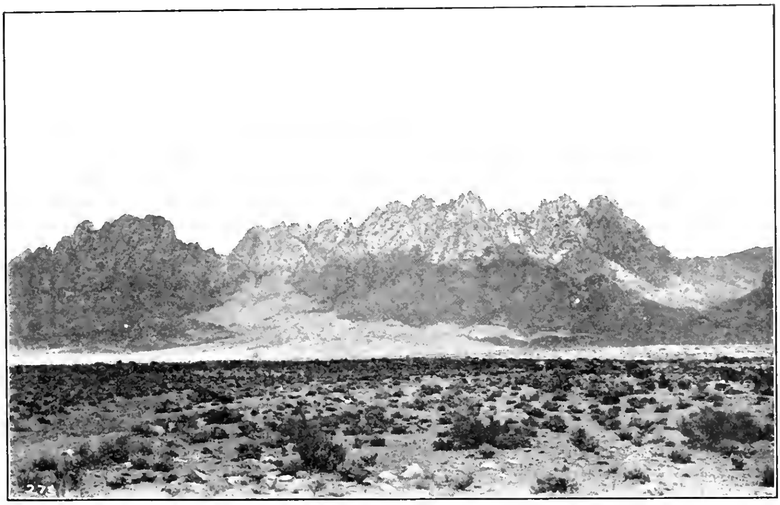
That the substructure of the intermont plains is made up of the softer or non-resistant rocks is an observation the full significance of which has been only lately appreciated. Under conditions of a moist or wet climate it is not an unlooked-for fact that the belts of weak rocks coincide with the valleys or lowlands. It is unexpected, however, that this is also true in an arid country, especially since the intermont plains are commonly considered as areas of extensive accumulations of mountain waste. On the whole they are now thought to be areas of most rapid degradation. The much stronger contrasts of belts of soft and hard rocks observable in the arid lands than in the moist lands appear to be due to this very fact. Then, too, wind-scour and not water-action must be reckoned with as the main erosional means, another fact that has not been usually taken into account.

Without exception the mountain rocks of the western deserts are very hard and resist the attacks of erosive action to an eminent degree. The plains rocks being mainly non-resistant rocks, as we have seen, there thus appears a notable alternation of hard and soft rock-belts. In the geologic succession the rocks composing the mountains are principally ancient crystallines and Paleozoic limestones which are followed by enormous thicknesses of soft sandstones and shales that frequently attain a vertical measurement of 10,000 feet or more. Tertiary faulting on a grand scale has brought the soft strata to the same level as the resistant beds. In the general and profound wearing down of the surface of the country towards sea-level, marked contrasts of relief are produced between the various rock-belts. In the moist countries the isolated residual eminences of general erosion, known to geographers by the special name of monadnocks, after the New England mountain regarded as the type, are of rare occurrence. In the desert region the majority of the mountains are of this character.

Sierra Oscuro, New Mexico. Rises out of plain like a volcanic isle out of the sea; height 4,000 feet; distance 15 miles. It is composed of hard rock; the plain of soft sandstones.

One of the most peculiar of the many odd features of the desert is the beveled rock structure of the plains-surface. In the moist regions a high-lying plain with the substructure beveled is taken as an indication of former peneplanation, the lowest level to which water can wear down the land. The intermont plains of the arid region of western America have beveled rock-substructures, but their surfaces are 5,000 to 8,000 feet above sea-level. The beveled character of the strata is almost conclusive evidence that these plains are not areas of extensive aggradation. In the absence of adequate water-action their origin must rest mainly in long-continued and effective deflation.

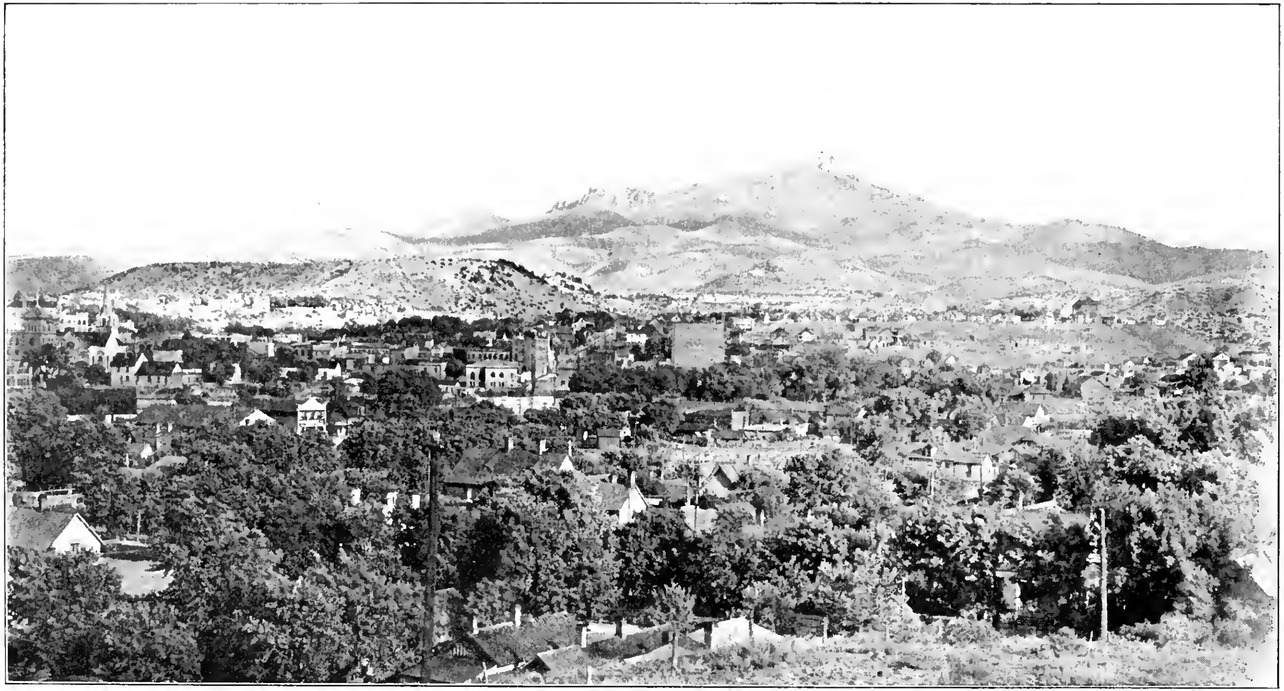
Critical examination of the substructure of the plains, in favorable places, shows clearly that the rock-floor itself is a plain. Although not always apparent at first glance this rock-floor is commonly only thinly mantled by wash débris and soil. Hence the rock-floor and the present plains-surface are not very different in their detailed relief characters.



SIERRA ORGANO. Striking example of absence of rock-weathering in arid country; the peaks rise 5,000 feet above the plain.

A phenomenal feature of the desert plains is the plateau-plain. Mesas they are called in southwestern United States and Mexico. These mesas, as their Spanish name signifies, are extensive, flat-topped, table-like areas rising abruptly from the general plain to heights of from one or two hundred feet to a thousand feet or more. The great Mesa de Maya, in northeastern New Mexico, is 3,500 feet above the next lower plain.

The surface of the plateau-plain is usually found to be composed of some hard rock layer, as in the case of the vast Llano Estacado, or "walled plains," or staked plains as it is called by the Texans; or is made up of an extensive lava flow, as, for example, the Mesa de Maya, the Ocate mesa and the majority of the plains of this kind. The surface beneath the lava flows of the mesas is itself a plain worn out on



Fisher Peak, a Spur of the Mesa de Maya, Colorado. It is 15 miles away and nearly 4,000 feet above the plain in foreground; a fine example of the plateau-plain.

the beveled edges of the strata. The plateau-plain thus represents a former position of the general plains-level. It is the best example of circumdenudation through vigorous wind-scour.

The soil mantle of the intermont plains is everywhere relatively thin. These plains instead of being areas of great accumulations of recent rock-waste, as might very naturally be expected, appear to be, as a rule, only thinly veneered. Often extensive areas are swept clean by the winds so that the rock-floor is exposed.

Nearly all of the finer surface detritus is transported from a greater or less distance. It is rare for the surface materials of the desert plains to give any suggestion of the rock-composition immediately beneath.

The gravely character of the intermont plains of the desert, to which travelers commonly allude, is largely only apparent. Most of the gravel-surfaced areas when upturned by the plow give excellent loamy fields. It is not generally recognized that the great abundance of pebbles on the surface of many plains is due to the fact that the strong and persistent winds blow away the finer materials, leaving a pebble mosaic behind.

While the rock-floor of the plains is itself a plain there are many inequalities in the surface. Between sheet-flood erosion and wind-drifted sands all local depressions are quickly filled. The tendency of the surface mantle is thus merely to make the plains smoother than they otherwise might be.

One of the most remarkable features which at once attracts the attention of the traveler is the general absence of distinct waterways in the valleys or intermont basins. Notwithstanding the fact that the gradients are high, no drainage systems are developed. Channel-ways that are corraded by unusual freshets, which sporadically occur, are quickly obliterated by the drifting sands and soils.

The degradation of the desert regions is not to be regarded as all accomplished by wind-scour. At times water plays a minor but important part locally. In the loftier mountain ranges normal torrential water-action takes place, much the same as it does in humid regions. The streams which are occasionally formed by heavy rainfalls soon sink into the ground on reaching the plain and become lost rivers. At other times, the stream-ways are without water for the greater part of their courses; arroyos, or dry creeks, the Spanish term them. McGee's vivid description of the advance of a flood-sheet over a piedmont slope is in reality the running of an arroyo as it enters a plain.

Water sometimes assumes another strange phase. The excessive local rainfalls which occur at rare intervals, "cloud-bursts" they are called, often form in the intermont valleys extensive shallow lakes. Most of these bodies of water are of short duration. When they are so situated as to be periodically renewed for a part of each year the areas become vast mud-flats, forming the playas of the Mexicans. Notwithstanding the fact that most of these lakes are ephemeral in character, they are sometimes long-lived. In the valley of the Rio Conchos, in the state of Chihuahua, the rainfall was once so heavy that in a single night a great lake was formed that lasted for more than eighty years.

A most singular phenomenon resulting directly from water-action in the desert is sheet-flood erosion. The vigor with which it often acts makes it locally an important plains-forming agent. Instead of the water from the rainfall tending to concentrate along certain lines of lowest level, as in humid regions, it spreads out over the sloping plains-surface. The railroads crossing the desert have yet to discover an effective method to overcome the disastrous work of the flood-sheet.

In the desert, however, extensive water-action is exceptional and relatively unimportant.

Not the least striking characteristic of desert regions is the marked absence of rock-weathering as we ordinarily know it. All exposed rock surfaces present an aspect of wonderful freshness. Chemical decomposition of rock-masses is all but unknown under the influences of a dry climate. The breaking down of the rocks is mainly mechanical, assisted somewhat by sand-blast action.

During the next decade the features of the arid portions of our earth promise to give us many novel ideas concerning the workings of certain of the geologic processes. To the scientist the desert will become one of the most interesting fields of research.

ON THE THERAPEUTIC ACTION OF FERMENTED MILK

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DURING the past year there has been in the United States a large increase in the use of fermented milk in the treatment of disorders of digestion and nutrition. A clearly discernible influence in bringing about this increase lies in the publications made by Professor Metchnikoff and his colleagues in reference to the fermented milk known as lacto-bacilline. The statements made by these scientific workers have been repeatedly exaggerated by persons having a commercial interest in the sale of certain kinds of fermented milks. It is apparently true that many physicians have been influenced by these statements in the direction of recommending among their patients a much wider use of fermented milk, and especially of lacto-bacilline, than was previously the case. Moreover many persons have decided without the advice of a physician to make a trial of some form of fermented milk or of some form of lactic acid ferment capable of acting upon milk sugar. It appears that this dietetic practise is still on the increase and likely to modify the habits of a not unimportant part of the community in respect to diet. In view of this fact it seems to me desirable to consider from a critical standpoint the therapeutic effects supposed to be derivable from the use of fermented milks, and more especially from milk that has been fermented through the use of the *B. bulgaricus* recommended by Professor Metchnikoff and now widely employed in the production of lacto-bacilline. I believe that at the present time there exists a considerable confusion of mind as to what may or may not reasonably be expected in the way of therapeutic results from the use of milk which has undergone lactic acid fermentation. It is the object of this paper to consider briefly the elements which should enter into the formation of a judgment as to the therapeutic efficacy of lacto-bacilline and allied milk products.

In order to be able to form an unimpeachable judgment on the therapeutic action of a fermented milk, it is necessary that experiments of a very painstaking sort should be carried on in a number of individuals for considerable periods of time. Experiments of a kind calculated to furnish a firm scientific foundation for a rational use of fermented milks have not yet been made. Such experiments in order to be decisive would have to be conducted not merely on people in good health, but also on a suitable variety of digestive and nutritional disorders in which the bacterial conditions in the intestine, the state of metabolism and the general conditions of life are taken into account with the greatest care and judgment. Although I have for many years been interested in watching the influence of fermented milk on the human organism in various states of digestive derangement, and have accumulated many observations bearing on the question, my experience falls far short of what is necessary to establish final conclusions. In this communication, therefore, I do not offer any solution of the therapeutic problems pertaining to the use of fermented milks, but seek only to discuss critically, in the light of such information as now exists, some of the claims that have been made for the employment of these kinds of milk. I do this with the thought that a discussion of the various elements which should enter into the formation of a judgment regarding the therapeutic value of milk subjected to lactic acid fermentation may prove helpful to those who have not given the subject much personal study and are therefore unable to analyze the problem in a way that is likely to serve as a practical guide.

There are five important kinds of effects referable to the action of fermented milks which must be considered in any judgment of the therapeutic effects of a milk which has undergone lactic acid fermentation. These are, first, the effects on the absorption of fats and proteins; secondly, the effects due to reduction of carbohydrates; thirdly, effects due to the presence of lactic acid; fourth, effects due to the bacteria used in lactic fermentation; fifth, effects due to a lowering of putrefactive decomposition. These latter effects, which are of the first importance in connection with any study of the action of fermented milk, are of course not entirely distinct from the others just mentioned, but stand related to each of these other factors. Owing to their prominence, however, it is desirable that they should be separately considered.

At present the influence of lactic acid fermentation upon absorption of the milk constituents is but little understood. The question relates especially to the absorption of fats and of proteins, for the carbohydrates of the milk are in large degree removed by the fermentative process, lactic acid, carbon dioxide and alcohol being the chief constituents resulting from the breakdown of the milk sugar. It is important that we should obtain exact data with regard to the absorption both of the fats and of the proteins, but, so far as I am aware, these do not at present exist. If it could be shown that the absorption of milk fat and of milk proteins is increased in health through the influence of lactic acid fermentation of any kind, this would be a distinct argument in favor of the use of such milk as an article of diet, since it would make for economy in the administration of the machinery of the body. Equally important and desirable are reliable observations on the effect of fermented milks on the absorption of milk fats and milk proteins in various types of intestinal infection with their accompanying acute and chronic catarrhal inflammation of the mucous membranes of the digestive tract. The therapeutic claims put forward by enthusiastic advocates of the use of fermented milk have in general taken a different direction and have concerned themselves much more with the question of the reduction in intestinal putrefaction than with increase in absorption. But it must not be overlooked that an improved absorption of proteins is one of the most important conditions in general for reducing intestinal putrefaction, because whatever favors prompt and complete absorption must correspondingly limit the opportunity for decomposition. In a lesser degree this statement holds true also of the fats. I have been able to show experimentally that in normal persons the butter-fat may be much increased above the usual intake—say from fifty grams to one hundred and fifty grams daily—without materially increasing putrefactive decomposition. On the other hand, such an increase in butter-fat in persons already suffering from increased putrefactive decomposition shows a pronounced tendency to still further increase the putrefaction. I attribute this tendency to the mechanical obstacle to prompt absorption of proteins arising from the presence of fat in abundance. The failure in prompt absorption of proteins from an intestine infected with putrefactive microorganisms means intense putrefaction, whereas a similar failure in a healthy intestine is far less significant owing to the relative infrequency of putrefactive bacteria.

In considering the therapeutic influence of fermented milk, it is necessary to take into account the fact that in such milk the carbohydrate material has been in a large degree replaced by the products of fermentation. Where milk is used in only small amounts in the dietary, and these small amounts are replaced by a fermented milk, the difference in quantity in respect to the intake of carbohydrates may be so small as to be negligible. Where, however, the dietary consists largely of milk and this large amount of milk is replaced by an amount of fermented milk equivalent in protein and in fat, the difference in respect to the carbohydrate material may assume considerable importance. In the case of the unfermented whole milk, there is enough milk sugar to markedly encourage fermentative decomposition in the intestine with the production of considerable gas. The gas-forming organisms especially likely to attack the milk sugar are *B. lactis ærogenes, B. coli* and *B. ærogenes capsulatus* (*B. welchii,* or *B. perfringens*). In cases where there is marked flatulence from the use of whole milk, the use of any fermented milk in which the milk sugar has been largely destroyed by fermentative bacteria introduces conditions unfavorable for intestinal fermentation. I consider that the diminution in fermentable material thus arising from the decrease in the carbohydrates of the milk is an important factor not merely in reducing intestinal fermentation, but also in reducing intestinal putrefaction, for it is true that in some intestinal infections in which we are justified in assuming that the colon bacillus or *B. ærogenes capsulatus* or both these organisms have extended in an upward direction toward the stomach, the abundant presence of fermentable carbohydrate pabulum leads to a great increase in these microorganisms. After the absorption of the acid produced in the course of this fermentation there may be established a neutral or even an alkaline reaction in the lower part of the small intestine and in the colon. In the absence of acid and indeed in the presence of a moderate amount of acid, the colon bacilli and *B. ærogenes capsulatus* are capable of making an increased attack upon the protein material. This increases intestinal putrefaction. On the other hand, the irritation arising from organic acids formed in the small intestine and stomach often leads to a fermentative diarrhœa.

Turning now to the effects attributable to the presence of lactic acid in the soured milk, it is at once apparent that we have to distinguish clearly between the action of such preformed lactic acid as may be introduced with the milk and such acid as may be formed in the course of further lactic acid fermentation after the soured milk has been ingested. The essential difference lies in the fact that such lactic acid as is preformed in fermented milk is liable to be absorbed from the upper part of the small intestine, whereas if lactic acid fermentation goes on within the digestive tract, the acid may be formed at any level of the intestine. In the former case the action of the acid is to be regarded as largely limited to the portion of the intestine in which putrefactive decompositions seldom occur; in the latter case there may be production of acid within the territory in which putrefactive decompositions are apt to take place. We should therefore expect greater anti-putrefactive efficacy from the use of soured milk containing living lactic acid producers than from the same milk after sterilization. Whether such a difference as this is actually discernible in practise I am unable to say, as I am not aware of the existence of satisfactory experiments made to test this point.

As to the efficacy of lactic acid as an anti-putrefactive agent it is necessary to speak with caution. It has been the practise of many physicians to employ lactic acid in the treatment of disorders of digestion, especially those of infancy. But I am unaware that we have adequate data for the establishment of the therapeutic anti-putrefactive value of lactic acid. Where the stomach secretes no free hydrochloric acid it is reasonable to suppose that the use of lactic acid in weak concentration exerts some anti-fermentative action, especially against such microorganisms as do not readily grow in acid medium. But there are many kinds of microorganisms in the digestive tract which are resistant to the action of lactic acid in the low concentration which can be tolerated by a somewhat irritable mucous membrane. Most yeasts and some important intestinal bacteria, such as *B. lactis ærogenes, B. bifidus, B. infantilis* and various organisms classed at acidophiles, have this property. It is a fact little known that some of the coccal organisms of the intestine resist the action of acid in a remarkable measure. It is therefore quite clear that anything approaching a significant modification of the activities of organisms of the types just mentioned is not to be looked for through the use of lactic acid. Moreover, I have shown that a considerable grade of acidity in the intestinal tract is consistent with very active fermentative growth of *B. ærogenes capsulatus.* This organism forms butyric acid during the fermentation of carbohydrates, together with only small quantities of lactic acid, and there is no reason to suppose that its development in the intestine is materially inhibited by any concentration of lactic acid which is likely to be obtainable in the lower part of the small intestine or in the colon, either as the result of administering lactic acid or in consequence of the use of soured milk.

That a considerable or high degree of putrefactive decomposition in the intestine is not controllable in man by the administration of moderate doses of lactic acid has become plain to me as the result of clinical observation. And that even very large doses of lactic acid are unable to restrict intestinal putrefaction is rendered highly probable from experiments made in my laboratory by Dr. Helen Baldwin. In dogs taking a meat diet and excreting urine characterized by abundant indican and high ethereal sulphates there was no falling off in putrefaction as a result of administering doses of lactic acid as large as five grams daily. It seems to me doubtful if under these circumstances enough lactic acid could reach the large intestine to exert even a moderate anti-putrefactive action. The experiments just mentioned represent an extreme case, since they were made on animals living exclusively on meat. The results obtained can not, therefore, be regarded as strictly applicable to man. Nevertheless these experiments are instructive as indicating the inefficacy of large doses of lactic acid in controlling intestinal putrefaction where the conditions for such putrefaction are favorable and where the acid is given under conditions rendering likely its absorption in the upper part of the digestive tract.

That the presence of lactic acid in soured milk does not necessarily exert a significant anti-putrefactive action in the large intestines is clearly shown by the observation which I have several times made that persons suffering from chronic intestinal putrefaction have shown no diminution in the putrefactive products excreted in the urine where the patients have added a soured milk to their usual diet. It is, of course, clear that in cases of this sort the failure of the putrefactive process to decline may be attributable to the introduction of more than the habitual amount of protein material. The observation is, however, of interest in that it emphasizes the fact that the ingestion of lactic acid, even if probably associated with lactic acid fermentation within the intestine, may not suffice to exert any beneficial influence in reducing putrefaction.

I do not wish to be understood as maintaining that the presence of lactic acid in soured milk is of no value in checking intestinal putrefaction. I wish merely to point out that the administration of lactic acid *per se* can not be regarded as a significant anti-putrefactive procedure. It seems to me probable, on the other hand, that the presence of lactic acid in the large intestine would at least in a degree tend to restrict putrefactive decomposition. But I must own that positive evidence on this point seems to be at the present time entirely wanting. In my judgment only very carefully planned studies would suffice to enable us to form a final opinion on the value of lactic acid as an anti-putrefactive agent. We are not justified in developing an enthusiastic attitude toward lactic acid as an agent in the inhibition of intestinal putrefaction on the basis of our present knowledge.

Let us now consider the effects derivable from the bacteria used in lactic fermentation. As an example of a strong lactic acid producer we may take *B. bulgaricus,* used in the production of lacto-bacilline. This organism is a powerful lactic acid ferment, forming large amounts of lactic acid from milk sugar while forming very little alcohol. The organism grows well in milk and on some media containing an abundance of soluble carbohydrates, as, for instance, in malt extracts. We may take the behavior of *B. bulgaricus* in the digestive tract as being typical of efficient lactic acid bacilli in general. There are two questions which we must put to ourselves regarding the therapeutic effects of such bacteria. First, to what extent do the lactic acid bacilli replace obligate normal types of bacteria or the undesirable saprophytic forms present in disease? Secondly, to what extent is it desirable that there should be a replacement of the intestinal flora by lactic acid bacilli?

It is one of the fundamental assumptions of the sour milk treatment of intestinal diseases that the lactic acid producing microorganisms establish themselves throughout the digestive tract and through their more or less aggressive growth directly or indirectly inhibit the development of putrefactive or other undesirable forms of bacteria. In some of the statements put before the public in regard to the action of the lactic acid bacilli it is claimed that they drive out other forms of bacteria from the large intestine, the chief seat of intestinal putrefaction. It is desirable that we should soberly consider the known facts relating to this question. I think it safe to say that the ability of lactic acid forms to replace or dominate other types of bacteria in the large intestine is much exaggerated. I have devoted some study to this question, especially in the case of the *B. bulgaricus* employed in the production of lacto-bacilline. This organism, owing to its large size, morphology and cultural peculiarities is easily recognized and is cultivable, from the intestinal contents. When given to human beings in the large numbers present in lacto-bacilline it can after a few days' administration be cultivated without difficulty from the movements. Even when large quantities of the fermented milk have been taken I have not found that it becomes the dominant organism, although it may be present in moderate numbers. On stopping the administration of the lacto-bacilline, the *B. bulgaricus* generally disappears in the course of a few days, showing that it has not permanently established itself within the intestinal tract. There may be exceptions to this statement, but I have not yet met with any. These clinical results are quite in accord with those obtained by Dr. Kendall and myself in experiments upon a monkey fed for two weeks on lacto-bacilline exclusively. At the end of this period, when the movements were showing the regular presence of *B. bulgaricus* in relatively moderate numbers, the animal was killed and the digestive tract examined with care at all its levels. The lactic acid organisms were found in greatest abundance in the small intestine. In the lowest portion of the small intestine a notable falling off was observed and other types of bacteria were prominent. In the large intestine the numbers were only moderate as compared with other varieties of bacteria, thus clearly showing that in this instance, at least, the *B. bulgaricus* was very far from dominating other associated types of bacteria. I consider this fact noteworthy, as the experiment was carried out under conditions highly favorable to the establishment of the lactic acid bacilli in the digestive tract. The large number of microorganisms given and the relatively short extent of the digestive tract in the monkey should, it would seem, provide conditions for the adaptation of the organisms throughout the alimentary canal.

It is probable that the experience just recounted with regard to lactic acid bacilli is not at all exceptional, or in other words that foreign bacteria in general find it difficult to gain a permanent footing in the digestive tract. The literature of experimental bacteriology shows this to be the case. Personal experiments made with a highly fermentative putrefactive organism—*B. ærogenes capsulatus* (*B. welchii* or *B. perfringens* of the French writers)—in feeding experiments on monkeys showed that in health these animals have the power of very quickly ridding themselves of this variety of bacteria. Experiments now under way with a microorganism described by myself and Dr. Kendall as *B. infantilis* and found very abundantly in some of the digestive diseases of children, show the same thing to hold true.

The fact that *B. bulgaricus* does not readily gain a dominant position in the digestive tract in man or in the monkey has an obvious bearing on the results to be expected from its therapeutic use. If it be indeed true that *B. bulgaricus* is capable by its presence in the intestinal tract of inhibiting undesirable types of bacteria and especially the microorganisms concerned with intestinal putrefaction, then it must be equally true that the difficulty in obtaining a dominant and permanent foothold in the intestinal tract is a fact with which we must reckon in any estimate of the results likely to be obtained through the administration of these organisms. The moderate representation of *B. bulgaricus* in the large intestine after the free administration of lactobacilline is surely something very different from what has been already frequently pictured by the enthusiastic upholders of the use of this form of fermented milk in the treatment of diseases of the digestive tract.

I think it has been assumed with far too little reason that the dominant presence of foreign microorganisms of the lactic acid group is necessarily a desirable thing. If it could be shown that lactic acid bacilli, such as *B. bulgaricus* or certain varieties of *B. acidi lactici,* have the faculty of replacing undesirable forms of microorganisms such as the bacilli of typhoid or of paratyphoid fever or putrefactive microorganisms, such as *B. proteus vulgarus* or *B. ærogenes capsulatus,* this would undoubtedly be cause for congratulation, especially if it could be shown at the same time that the normal flora of the digestive tract remained unchanged. I do not deny the possibility that this selective kind of anti-bacterial action may some day be proved to exist. I desire merely to point out that at present I know of no facts to justify us in believing that such antagonistic action as the lactic acid bacteria may possess is directed solely against the disease-inciting invaders of the digestive tract. If it should prove true that the antagonism exerted by the lactic acid bacilli against injurious invaders is also exerted against the obligate bacterial inhabitants of the alimentary canal, such as *B. coli communis* and *B. lactis ærogenes,* I am by no means convinced that this could be regarded as a point in favor of the prolonged therapeutic use of lactic acid bacilli. If, as appears to be true, these obligate inhabitants of the digestive tract are especially adapted to the normal conditions of secretion and digestion in the human intestine and tend to be suppressed in some serious conditions of the digestive tract (while their reappearance and reestablishment in abundant numbers is one of the first, most definite and most reassuring signs of improvement in the clinical condition of certain kinds of patients) to make use of any mode of lactic acid bacillus therapy which will inhibit the normal development of *B. lactis ærogenes* or *B. coli communis* in the digestive tract would, in my judgment, be a profound error in principle. I do not wish to intimate that I consider *B. bulgaricus* or any of the common lactic acid bacilli to be capable of seriously checking the growth of *B. lactis ærogenes* and *B. coli communis* in the digestive tract, but wish to state that in so far as such modification is possible it appears to me not without undesirable features. To the validity of this statement there is one possible exception that occurs to me. In cases where there is a colon bacillus infection of the intestine, that is to say, an inflammatory state associated with a great over-growth of *B. coli,* the antagonistic influence of lactic acid bacilli might be useful. But I am not sure that this is more than a merely apparent exception to the general rule which I have above expressed as valid, for it is not clear that it has been proved that the colon bacilli apparently answerable for digestive infections are in reality the normal colon bacilli. It appears to me more likely that they are commonly variants of such bacilli whose fermentative characters have not yet been determined fully and precisely.

I would also mention here the fact that there are diseases of the intestinal tract associated with the presence of bacteria capable of forming lactic acid. Obviously, then, this property of a microorganism does not necessarily screen the digestive tract from injury.

One of the most important and most loudly heralded effects of the administration of soured milk is that on intestinal putrefaction. Under conditions of health the putrefactive decompositions in the intestinal tract seldom attain a considerable degree of intensity—a surprising fact when we consider the immense numbers of bacteria which inhabit the large intestine. In many pathological states the conditions of putrefaction in the intestine are very much altered in the direction of great intensification. This is shown both by the dominance of putrefactive microorganisms in the large intestine and by the appearance of products of putrefaction in the urine. It is unnecessary here to discuss the nature of these products. It should, however, be pointed out that the intensity of putrefaction as judged by the quantity of putrefactive products in the urine is notably influenced by the quantity of protein material ingested. We may say that in general a considerable increase in the protein intake is followed by a corresponding increase in putrefaction and that a marked diminution in protein intake is followed by a distinct falling off in putrefaction. This statement holds true in general in conditions of health and it is even more strikingly exemplified in cases of chronic intestinal infection associated with habitual excess in putrefaction. In view of this fact it is clear that in experiments designed to determine the influence of fermented milks upon the intensity of putrefaction it is essential to take accurate cognizance of the quantity of protein ingested. It is easy to understand that if a patient has been in the habit of eating for his midday meal an abundance of protein food and decides under advice to take a fermented milk for his lunch in place of the more elaborate meal, the mere reduction in protein will suffice to reduce putrefaction. So it is clear that a decrease in putrefaction can be effected through a variety of dietaries which have in common the fact that they contain a smaller amount of protein material than the patient has been in the habit of eating. Whole milk and various fermented milks are thus capable of influencing putrefaction in such a way that we may readily fall into the error of exaggerating their influence upon putrefactive decomposition in the intestine. Hence it is evident that the only fair test of the value of a fermented milk in respect to its influence on putrefaction is to compare it with the effects of other articles of diet containing exactly the same amount of protein material. Such careful comparisons have not, I believe, been made up to the present time. In the future they will doubtless be made and will enable us to form quite definite judgments as to the relative effectiveness of different kinds of fermented milks upon intestinal putrefaction. At present I should hesitate to say that one kind of fermented milk is more effective than another in bringing about a reduction in intestinal putrefaction.

We may regard it as well established that a diet in which milk takes the place of other kinds of food is very apt to be followed by a reduction in the intensity of putrefactive decomposition in the intestine. There are, however, clinical indications that the use of fermented milks does possess real advantages over the use of whole milk at least in some disorders of digestion. Although the exact character of these advantages is not yet firmly established, they seem to be none the less real. From what has already been said in this paper on the criteria of judgment of the action of fermented milks, it is evident that the clinical advantages which have been observed may be attributable to several different peculiarities possessed by fermented milks in general. One of these is the favorable mechanical influence on the minute subdivision of the casein, which prevents the undesirable effects associated with the presence of large clots of casein which are not easily disposed of in persons with weak digestion. The exact consequences of this advantageous mechanical state of the milk food can not now be appraised. A second point which has already been mentioned is the formation of lactic acid. Here again the precise extent of the favorable influence can not be measured; but on the other hand it can not be denied that in at least some disorders of digestion the presence of lactic acid in the intestinal tract may exert a degree of anti-putrefactive action. It should, however, be remembered that there are persons with chronic inflammatory states of the digestive tract who tolerate very badly acids of all sorts. These persons are unable to take considerable quantities of fermented milk if the milk contains a high percentage of lactic acid, the attempt to utilize such food being followed by various unpleasant sensations and diarrhœa. The possible anti-putrefactive influence of the presence of living lactic acid bacilli in various parts of the digestive tract has already been discussed at sufficient length and it has been pointed out that this factor again is one whose value can not at present be accurately estimated.

It must be plain from what has been said that the therapeutic use of fermented milks rests at the present time rather more securely on the clinical observations that have been made with it than on an adequate scientific study of the influence exerted upon digestion and nutrition and especially on the processes of putrefaction. To obtain the necessary scientific data will require elaborate and very laborious experiments covering long periods of time. With the aid of such experiments I have no doubt that the usefulness of soured milks in health and in disease will be definitely and discriminatingly established. The limitations of utility will become equally plain, and I predict that they will prove to be many. The importance of this subject for the welfare of people at large not only in respect to immediate physical comfort and efficiency but as regards the prolongation of life, would, in my opinion, amply justify a very considerable expenditure of money to acquire this knowledge.

It can not be regarded as surprising that the enthusiasm which has been aroused partly through the public exploitation of various kinds of fermented milk in the treatment of disease and partly by the undoubted successes of the treatment should have led to various abuses. One of the most important things to understand in reference to the use of fermented milk is that it should be employed in most instances as a substitute for other forms of food rather than as an addition to the usual dietary. Especially is it necessary to bear this in mind in the case of chronic disorders associated with an increase in putrefaction. The addition of a considerable amount of fermented milk to the habitual dietary has often been practised with disastrous results, and I do not doubt that this practise is still widely extended. Such bad results might be predicted, for since all fermented milks contain a large proportion of protein material capable of undergoing putrefaction and since this putrefaction is not checked, in any specific way, through the agency of the fermented milk itself, a great increase of putrefactive decomposition may follow the injudicious excessive use of such food. I have seen several instances of this error, which is not confined to laymen, but is sometimes committed by physicians also.

Another feature of fermented milk which needs to be closely scrutinized is the character of the microorganisms employed as ferments of the milk. In a few instances I have known to be used as ferments what I believe to be very undesirable types of bacteria. I think it may be said that most of the fermented milks on the market in this country at the present time contain chiefly fermentative organisms which are harmless when not excessively administered. In some cases the lactic-acid producing bacteria have become contaminated by possibly undesirable yeasts. It is only natural that accidents of this sort should occur in what is comparatively a new industry, and it is likely that with increasing experience the manufacturers of the various fermented milks will be compelled to exercise every reasonable caution in regard to the purity and quality of the ferments employed in their products.

The use of tablets of other preparations of lactic acid bacilli is now becoming widespread. The tablets are taken with some carbohydrate material which will permit the growth of the bacteria and the formation of lactic acid. I have seen good results from this method of using lactic acid bacilli, in the relief of symptoms referable to excessive intestinal putrefaction. But I do not think the data exist at present for an intelligent comparison of this use of lactic acid bacilli with their use in fermented milks. I hope before long to be able to discuss this question on the basis of experimental observations.

POETRY AND SCIENCE: THE CASE OF CHARLES DARWIN

BY EDWARD BRADFORD TITCHENER

IN the autobiographical chapter of the "Life and Letters of Charles Darwin" occurs a well-known passage, in which the writer deplores his loss, in middle life, of the higher esthetic tastes.

> Up to the age of thirty, or beyond it, poetry of many kinds, such as the works of Milton, Gray, Byron, Wordsworth, Coleridge and Shelley, gave me great pleasure, and even as a schoolboy I took intense delight in Shakespeare, especially in the historical plays. . . . But now for many years I can not endure to read a line of poetry: I have tried lately to read Shakespeare, and found it so intolerably dull that it nauseated me. . . . This curious and lamentable loss of the higher esthetic tastes is all the odder, as books on history, biographies, and travels (independently of any scientific facts which they may contain), and essays on all sorts of subjects interest me as much as ever they did. My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I can not conceive. A man with a mind more highly organized or better constituted than mine would not, I suppose, have thus suffered; and if I had to live my life again, I would have made a rule to read some poetry . . . at least once every week; for perhaps the parts of my brain now atrophied would thus have been kept active through use. The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature.

The loss which Darwin here regrets has often been charged to the particular account of his occupation with science. I have always believed that the charge is unfounded. It is difficult to give precise reasons, to translate into words what is, at bottom, a matter of general cumulative impression; but I shall attempt to show that there are, at any rate, plausible grounds for doubting the common construction put upon his remarks.

I must begin by saying that there is no real evidence to the effect that Darwin showed, at any period of his life, a deep feeling for poetry, or a profound understanding of it. I use the adjectives advisedly. The true love of poetry, and the intimate understanding of poetry, are matters primarily of a man's temperament. But they are also, like everything else that is worth while, largely—much more largely than is ordinarily supposed—matters of technique, of long and studious apprenticeship. Temperament and training, then, must go together, if anything more than superficial interest is to result. Now Darwin's temperament was scientific: "My love of natural science," he writes, "has been steady and ardent." I suggest that the combination in a single individual of the scientific and the poetic temperaments is and must be rare. And I suggest, further, that, where it occurs, the temperament will almost inevitably develop one-sidedly, so that poetry outtops science, or science poetry.

In Goethe's case, poetry was in the ascendent. As I said above, I do not think that Darwin had any large admixture of the poet in his make-up; certainly not so large an admixture of poetry as Goethe had of science. But I believe that he had something of the poet in him; I believe that the atrophy of this something went less far than he himself imagined; and I believe that science is not specially responsible for its partial loss.

Every normal man is a poet for a few years of his life. With most of us, the poetic interest and inspiration die out, as naturally and almost as suddenly as they came, somewhere about the age of twenty-five, and usually sooner rather than later. Darwin was a man of genius, and like many other men of genius he came late to maturity; his plastic period extended, as he himself declares, "up to the age of thirty or beyond it;" and the "Origin of Species" was published in 1859, when he was fifty years old. Perhaps as a result of this prolongation of adolescence, perhaps as a coordinate feature of his extraordinary endowment, Darwin possessed the poetic gift, the gift of creative imagination, in a marked degree. He writes:

> I have steadily endeavoured to keep my mind free so as to give up any hypothesis, however much beloved (*and I can not resist forming one on every subject*), as soon as facts are shown to be opposed to it. . . . On the other hand, *I am not very sceptical*—a frame of mind which I believe to be injurious to the progress of science.

Here is the poetic temper showing, quite unconsciously to its possessor, through the overlay of scientific training; here we get a glimpse, not of "a kind of machine for grinding general laws out of large collections of facts," but of the credulous and imaginative attitude of the poet.

If I am right in my interpretation, and if Darwin, while never profoundly poetical, still had more than the common share of poetic insight, then we ought to find traces of this character in his books. We must not expect too much, for Darwin pruned his manuscripts to the quick. His son tells us:

> He had a horror of being lengthy, and seems to have been really much annoyed and distressed when he found how the "Variation of Animals and Plants" was growing under his hands. I remember his cordially agreeing with Tristram Shandy's words, "Let no man say, Come, I'll write a duodecimo."

We shall not, then, look for poetic quotations in the "Variation." If Virgil is cited, it will be only in connection with the choice of seed corn; and if Homer is mentioned, it will be only because there is no mention of *Gallus bankiva* either in the "Iliad" or in the "Odyssey." Nor shall we look for poetic excerpts in the "Origin," that wonder of compressed argumentation. But we may fairly turn to the "Naturalist's Voyage," and to the "Expression of the Emotions," and to the "Descent of Man." And if we do, our search will be rewarded.

When, for instance, Darwin is describing in the "Voyage" the feasting of the Indian troops at Bahia Blanca, he not only gives a description which is itself reminiscent of Virgil, but he quotes, in the most natural manner possible, the very words—

> Nam simul expletus dapibus, vinoque sepultus
> Cervicem inflexam posuit, jacuitque per antrum
> Immensus, saniem eructans, ac frusta cruenta
> Per somnum commixta mero—

in which Virgil in the third book of the "Æneid" describes the gorging of Polyphemus. And when he is surveying the desert behind Port Desire, on the Patagonian coast, he says:

> All was stillness and desolation. Yet in passing over these scenes, without one bright object near, an ill-defined but strong sense of pleasure is vividly excited. One asked how many ages the plain had thus lasted, and how many more it was doomed to continue.
>
> None can reply—all seems eternal now.
> The wilderness has a mysterious tongue,
> Which teaches awful doubt.

It is only fair to say that the passage from Virgil occurs in the first draught of the "Voyage," which appeared in 1839 (when Darwin was thirty) as part of Fitz-Roy's work. But then it is also fair to say that the passage from Shelley's "Mont Blanc" occurs for the first time in the edition of 1845.

The "Descent of Man" was published in 1871, when its author was sixty-two. In it he quotes from Tennyson's "Idylls of the King" (1859) the words of Guinevere—

> Not ev'n in inmost thought to think again
> The sins that made the past so pleasant to us—

and, in the second edition (1874), Hookham Frere's rhymed version (1872) of Theognis, Fragment X. The quotation from the Greek poet Xenarchus—"Happy the Cicadas live, since they all have voiceless wives"—bears witness, perhaps, rather to Darwin's sense of humor than to his love of poetry.

The "Expression of the Emotions" came out in 1872, when Darwin was sixty-three. Here he cites from "King Henry VIII." Norfolk's account of Wolsey's "strange commotion," and from "King Henry V." the king's picture of warlike anger. The former passage is correctly given; the latter is printed with some curious omissions, which are not indicated; probably it was written down from memory. The book contains, further, quotations from "King Richard II.," "King Henry IV.," pt. i., "King Henry VI.," pt. ii., the "Merchant of Venice," "King John," "Julius Cæsar," the "Winter's Tale," "Titus Andronicus," "Romeo and Juliet" and "Hamlet." Not a bad list for a man who, four years later, was to declare that he has "tried lately to read Shakespeare, and found it so intolerably dull that it nauseated me!" Here Shakespeare is neither dull nor intolerable, but endowed with "wonderful knowledge of the human mind." And it must be understood that the passages quoted are not taken, haphazard, from a Shakespeare concordance. I have worked through the thirty-seven plays myself, with a view to emotive psychology, and I know what the possibilities of quotation are. Darwin's passages are selected, and I have little doubt that they were remembered first and looked up afterwards. Darwin quotes, again, from Somerville's "Chase" the lines—

> And with a courtly grin, the fawning hound
> Salutes thee cow'ring, his wide op'ning nose
> Upward he curls, and his large sloe-black eyes
> Melt in soft blandishments, and humble joy—

which may pass for poetry. He quotes the "laughter, holding both his sides" from Milton's "L'Allegro"; he quotes twice from Worsley's rhymed version of the "Odyssey"; he refers to the laughter of the gods in the first book of the "Iliad";[1] and he quotes twice from the "Æneid" of Virgil.

I hope that these illustrations of Darwin's use and knowledge of poetry are enough, if not to prove my point, at any rate to give it plausibility. It is, perhaps, not wholly superfluous to add that the absence of certain apt quotations from Darwin's pages is adequately explained by the circumstance that the poets are post-Darwinians. I have found more than once, in discussing this question, that even highly educated persons may be a trifle hazy in their dates.

When, on the other hand, we ask whether Darwin would have retained his poetic sense by weekly readings, the answer must be doubtful. If he had read with any overt intention of refreshing the intel-

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[1] So I have always interpreted the rather puzzling passage at the beginning of chapter VIII. My colleague, Dr. L. L. Forman, suggests, however, that Darwin may have confused the Greek with the Norse gods. If this is the case, the reference is probably to some prose work upon Norse mythology.

lect or building up the moral character, then very certainly the effort would have ended in failure; poetry must be taken for its own sake, or it may as well not be taken at all. I incline to the opinion that the readings, while they would undoubtedly have increased the store of possible quotation, would still have left Darwin with the regrets that the "Autobiography" expresses.

The argument of the present note may now be summarized as follows. I do not think that Darwin ever had a profound interest in poetry; the scientific temperament was too strong in him. The historical plays in which as a schoolboy he took "intense delight" probably interested him in the main as stories. The poets whom he read during his plastic period probably attracted him, in large measure, by their felicity of language; the cult of words and phrases is characteristic of adolescence, and is curiously different from a real appreciation of style—into which it may or may not develop, according to the temperament of the reader. On the other side, I think that Darwin's poetic leanings were much more pronounced and much more persistent than those of the average man of science. By his own unconscious confession, and by the evidence of his written works, his mind was leavened with poetic feeling; all through his mature life he is ready with quotation when the occasion calls; and the very poignancy of his regret for the loss of poetry witnesses to his poetic endowment. If and in so far as he did lose his poetic interests, the loss was due, not specifically to his occupation with science, but generally to the combination of a stupendous life-work with continued ill-health. "For nearly forty years he never knew one day of the health of ordinary men," and in those forty years he revolutionized biology. Small wonder, then, that he had neither time nor energy for that critical cultivation of poetry which, however gifted the temperament, is the *sine qua non* of a true poetic insight. It was not that addiction to science brought with it an atrophy of the higher esthetic tastes. It was rather the fact that an esthetic power, distinctly above the average, though not of the first rank, was left, by the demands of an absorbing pursuit upon a frail constitution, to work itself out unguided, and to show itself as best it might. The cry that Shakespeare is intolerable is the cry of a man to whom Shakespeare is familiar from cover to cover, tragedy and history and comedy, and for whom Shakespeare might, under other circumstances, have been a source of never-ending delight.

I have spoken only of poetry. The considerations which I have here urged apply, however, with the necessary modifications, to Darwin's loss of pleasure in pictures and music.

A BIOGRAPHICAL HISTORY OF BOTANY AT ST. LOUIS, MISSOURI. II.

By Dr. PERLEY SPAULDING

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THOMAS DRUMMOND[9] was born about 1780. He is known to have been a native of Scotland, but the exact place of his birth is unknown, as is also his early training and education. He was a brother of James Drummond, the Australian botanical explorer, and is known to have succeeded George Don in the nursery at Forfar. In 1825–6–7 he accompanied the Second Overland Arctic Expedition, led by Sir John Franklin, as assistant to Dr. Richardson, who was the naturalist of the expedition. In Canada Drummond explored very extensively, even into the Rocky Mountains and on the Mackenzie River where the main part of the expedition did most of its work. Upon the completion of the journey he returned to England, and from 1828 to 1829 he was curator of the Belfast Botanical Garden. Soon after his return to England he published a work upon the American mosses, which was chiefly the result of his collections made in Canada. He again sailed for New York under the patronage of Drs. Hooker and Graham, for the purpose of exploring the southern and western United States. Beginning his tour at New York City in the spring of 1831, he went to Philadelphia, visited Bartram's garden, thence to Baltimore, Washington, and to Wheeling on foot. At the last-named place he embarked for St. Louis, descending the Ohio River and coming up the Mississippi by boat. It was his original intention to join some fur-trading expedition to the far western country, but he arrived in St. Louis too late for this. He accordingly remained in St. Louis and collected in the vicinity until the next winter. He lost considerable time by sickness, but in January he sent a collection of several hundred species of phanerogams and a considerable collection of mosses and hepatics to Hooker at Kew. Hooker

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[9] Date of birth and photograph supplied by Mr. J. R. Drummond, grandson of Thomas.

Hooker, Wm. J., *Companion to the Jour. of Bot.*, 1: 21–26, 39–49, 95–101, 170–177, 1835; 2: 60–64, 1836. *Journal of Botany*, 1: 50–60, 183–202, 1834. *Botanical Miscellany*, 1: 178, 1849.

Lasègue, A., "Musée Bot. de M. Benj. Delessert," 196–198, 1845.

Sargent, C. S., "Silva of North America," 2: 25, 1891.

FIG. 3. THOMAS DRUMMOND.[9a]

From a crayon portrait at the Kew Gardens; by permission of the Kew Garden authorities, through the kindness of Mr. J. R. Drummond, grandson of Thomas.

seems to have prepared his collections for distribution, and we find him publishing a list of about two hundred and fifty species which were collected around St. Louis by Drummond.

During the next spring and summer Drummond collected in the vicinity of New Orleans, and here he obtained even more plants than he did at St. Louis. He next went to Texas, which he was one of the first to explore botanically. Here he gathered a rich harvest, in spite of a season of the most unfavorable weather. He then returned to New Orleans and went to Appalachicola in 1835 for the purpose of exploring the Florida peninsula. He soon left western Florida with the intention of reaching Key West by way of Havana, Cuba. Hooker learned that Drummond was taken sick while at Havana and died very suddenly in March, 1835.

Harvey dedicated the genus *Drummondita* to the two brothers.

[9a] By an unfortunate error, this portrait of Thomas Drummond was in the last issue of the MONTHLY printed as a portrait of William Baldwin, and the portrait of William Baldwin was printed as the portrait of Meriwether Lewis.

FIG. 4. PRINCE MAXIMILIAN: from his "Reise nach Brasilien."

Very appropriately *Drummondia,* a genus of American mosses, was named in Thomas's memory by his patron, Sir William Jackson Hooker. Numerous species of our phanerogams are also named after this most industrious and successful collector.

Even persons of royal lineage were numbered among the many naturalists who came to America for the purpose of exploring unknown sections for new plants and animals, and to make scientific observations. While Prince Alexander von Humboldt attained eminence for his travels and scientific worth, he was not the only royal person who did so, although we generally hear no other mentioned. Alexander Philip Maximilian, Prince of Wied neu-Wied, came to the New World on two different occasions. On the first tour he visited Brazil, and on the second he visited the United States and especially the northwestern or Missouri country.

Prince Maximilian[10] was born on September 23, 1782, in Wied

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[10] Thwaites, R. G., "Early Western Travels," Vols. 22, 23 and 24.
Maximilian, Prince, "Reise nach Brasilien," 1820-1.
Sargent, C. S., "Silva of North America," 9: 138, 1896.

neu-Wied, a small principality of Rhenish Prussia. He was from boyhood of a studious inclination, and early became interested in the natural sciences. In spite of this he was in the Prussian army at the battle of Jena, and was among those captured by the enemy. He returned to his studies at the end of this war, but was among the victorious army which entered Paris in 1813. In this service he earned the iron cross of Chalons and a major-generalship. During all of this time he had been planning a scientific expedition to Brazil in order to satisfy a keen desire to add to the world's knowledge, imparted to him by the celebrated Professor Johann Friederich Blumenbach, of whom he was a favorite pupil. Early in 1815 he started for Brazil. He was joined in South America by two other German scholars, and the trio spent two years studying the flora, fauna and native races of this country. His resulting publications gave him a high rank among the scientists of the period, and his "Reise nach Brasilien in den Jahren 1815 bis 1817" was soon translated into the French, English and Dutch languages.

In 1832 Prince Maximilian started on a second enterprise—a trip to the trans-Mississippi region. He arrived in Boston on the fourth of July. He brought with him a very capable artist, for the express purpose of obtaining portraits of famous Indians. He made more or less brief visits to Boston, New York and Philadelphia, and then went to Bethlehem, Pennsylvania, and thence through the coal region, reaching Pittsburg in the autumn. The journey was then continued overland to Wheeling, where they embarked for the voyage down the Ohio River. They turned aside for the purpose of visiting New Harmony, Indiana, where then was located the best library of American and natural history west of the Atlantic seaboard. Here the winter was spent studying and preparing for the journey on the Missouri River. On March 16, 1833, the journey was resumed and they arrived in St. Louis before the fur-trading expeditions had left on their annual trip to the northwest. Following the advice of several St. Louis men, the journey was made by boat up the Missouri River, instead of by land, as was at first planned. On April 10 the journey was commenced, and by the twenty-second they had reached Fort Leavenworth. The expedition was continued to Fort McKenzie, on a branch of the Yellowstone River, among the Blackfeet Indians, where they remained for two months. The return trip was begun on September 14, and the succeeding winter was spent at Fort Clark, near the present town of Bismarck, North Dakota. The next spring Prince Maximilian returned to St Louis and journeyed eastward by way of the Ohio canal and Lake Erie to New York, where he embarked for the Old World on July 16, 1834. Upon returning from the upper Missouri country the collections which had been made were left behind to be sent down the river in another steamer which was soon to follow the one carrying the party. A fire broke out on this steamer and many of the collections were destroyed because they were not deemed of as much value as other things which were on board.

After his return to his native city Prince Maximilian worked over his collections and other material with the aid of a number of experts, and published several papers upon his results. In 1843 he published his "Systematic View of Plants Collected on a Tour on the Missouri River." His collections are preserved in the museum of his native city, where he died in 1867.

Martius honored him by naming a genus of Brazilian and West Indian palms, *Maximiliana,* thus very appropriately connecting him with the botany of that country, of which he was one of the pioneer explorers.

Hardly had Prince Maximilian started for home before another explorer was at work on the Missouri. This person was none other than Thomas Nuttall, the greatest botanist of this country in his time. As has been already mentioned, he had visited this section in company with John Bradbury in 1811.

Thomas Nuttall[11] was born in the town of Settle, England, in the year 1786. His parents were in very moderate circumstances, and the boy was early apprenticed to a printer. After several years he had a disagreement with his employer and went to London seeking for work. Here he came very near total destitution. When about twenty-two years of age he emigrated to America, landing in Philadelphia. During his youth he so improved his spare moments that he acquired an intimate knowledge of the Latin and Greek languages, and he seems to have studied other branches, as he was described at the time of his landing as "a well-informed young man, knowing the history of his country, and somewhat familiar with some branches of natural history, and even with Latin and Greek." Nuttall knew nothing of botany at this time, but very soon after he became interested in the "amiable science," and also began an acquaintance with Dr. Benjamin Smith Barton. His studies of plants naturally led him into making short excursions which soon lengthened as his interest deepened, until he had visited the lower part of the Delaware peninsula and the coast region of Virginia and North Carolina.

At about this time Nuttall became acquainted with John Bradbury, and he eagerly proposed to accompany him on his trip up the Missouri River. Accordingly, Nuttall joined Bradbury at St. Louis, and early

[11] Short, C. W., *Transylvania Jour. of Med.*, etc., 34: 14–16, 1836.

Meehan, Thos., *Gardeners' Monthly*, 2: 21–23, 1863.

Durand, Elias, *Proc. Amer. Phil. Soc.*, 7: 297–315, 1860.

Sargent, C. S., "Silva of North America," 2: 34, 1891.

Britten, Jas., and Boulger, G. S., "Biographical Index of British and Irish Botanists," 129, 1893.

Anonymous, Pop. Sci. Monthly, 46: 689–696, 1895.

Harshberger, J. W., "Botanists of Philadelphia," 151–159, 1899.

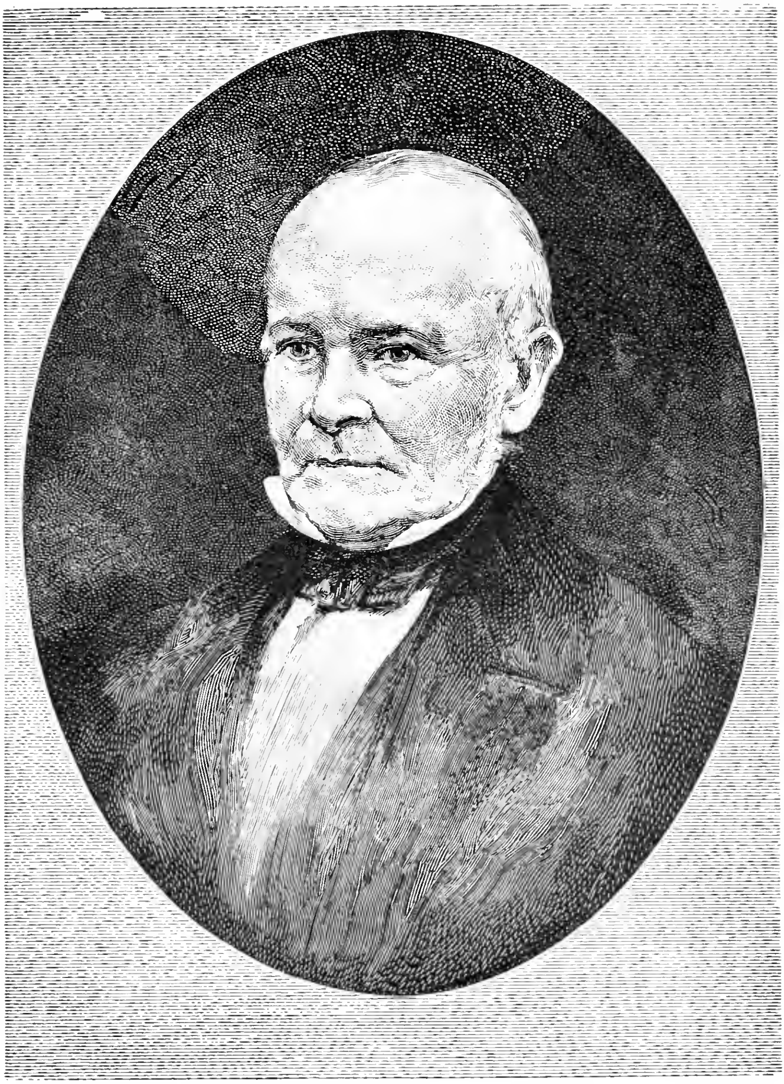

FIG. 5. THOMAS NUTTALL; from THE POPULAR SCIENCE MONTHLY, Vol. 46, 1895.

in the spring of 1811 the two made the journey up the river to the Mandan villages, as previously described in this paper. Both naturalists were more than once in extreme danger, but Nuttall brought back with him many treasures of seeds, plants and other objects of interest. The next eight years he remained at Philadelphia, studying in the winter the collections which he made during his summer excursions to various parts of the country east of the Mississippi, from the Great Lakes to Florida. At about this time he was preparing the manuscript

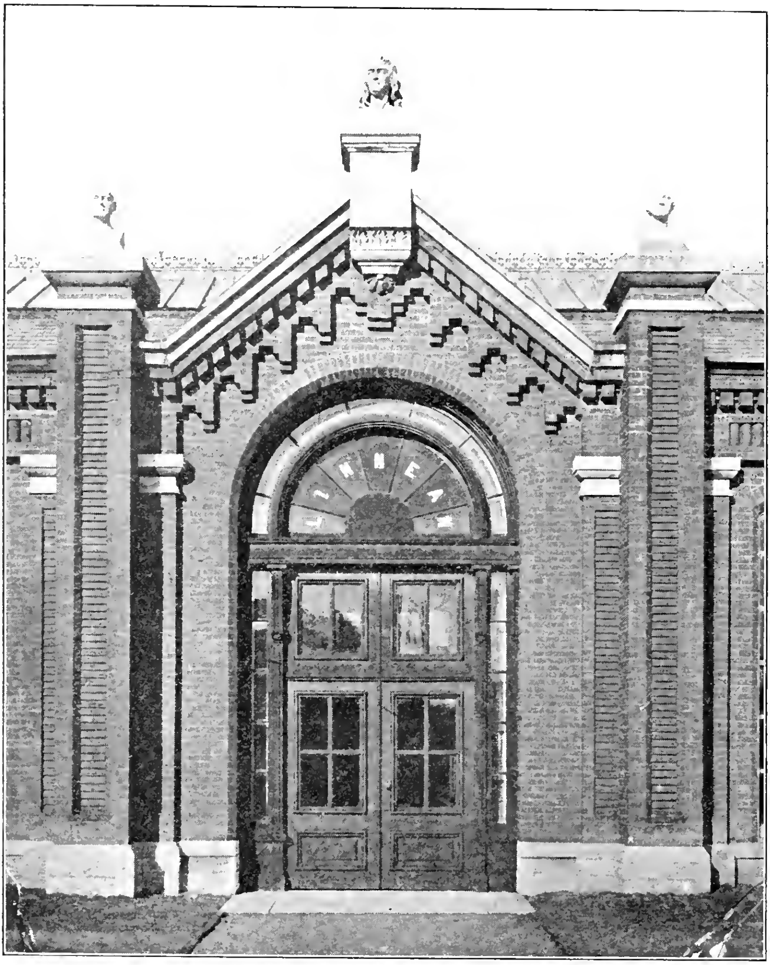

FIG. 6. ENTRANCE OF THE LINNÆAN GREENHOUSE AT THE MISSOURI BOTANICAL GARDEN, ST. LOUIS, MISSOURI; showing the three busts of Linnæus, Gray and Nuttall.

for his "Genera of the North American Plants," which did not appear until 1818. Nuttall himself set most of the type for this work. In 1818 he started from Philadelphia for Arkansas, reaching Fort Bellepoint on April 24, 1819. He made this his center of operations, exploring in various directions and making large collections. He was taken sick with fever and on recovering made one more excursion and then set out for home, reaching New Orleans February 18, 1820. At this time he had made a journey of over five thousand miles through a country still in the undisputed possession of the Indians, and almost wholly unexplored by scientific men. Immediately upon his return to Philadelphia in 1820 he began to study his collections and to write his

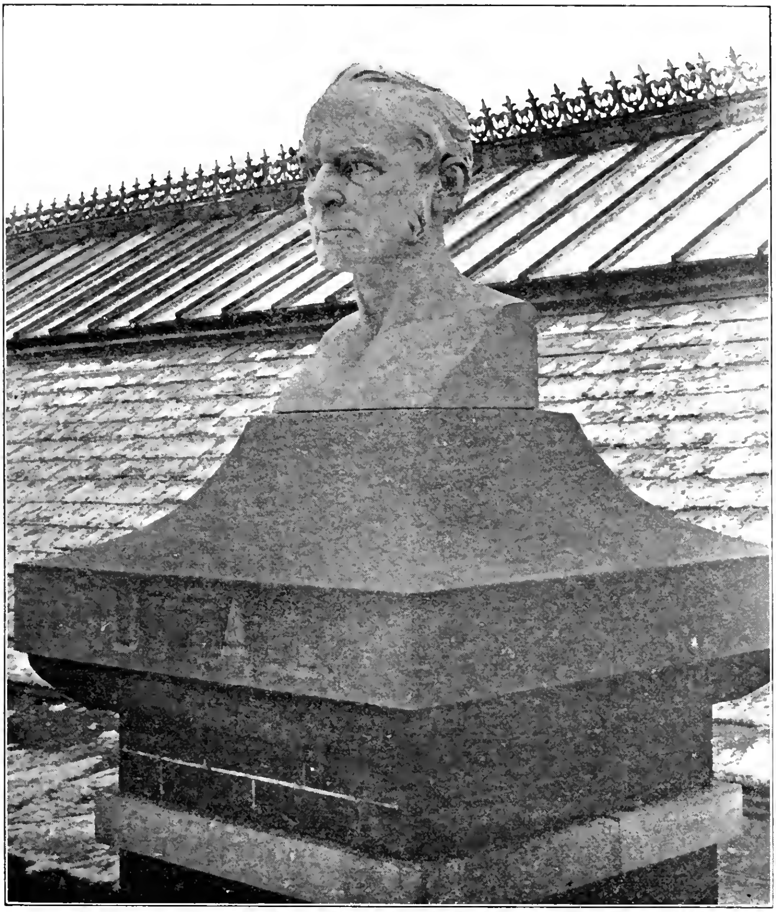

FIG. 7. BUST OF THOMAS NUTTALL over the entrance of the Linnæan Greenhouse at the Missouri Botanical Garden, St. Louis, Mo.

"Journal of Travels into the Arkansas Territory During the Year 1819," which was published the following year.

At the end of 1822 he was called to Harvard College as curator of the botanical garden, there not being enough money to support a professorship. He soon became dissatisfied with this and took up the study of ornithology, producing a two-volume manual of this science. About the beginning of 1833 Nuttall went to Philadelphia with the collection of plants made by Captain Wyeth during an overland journey to the Pacific Ocean. A second journey was to be made and Nuttall resigned his position and spent the interval before the departure of the expedition studying the Wyeth collection and his own Arkansas plants.

Mr. Nuttall went in company with John K. Townsend, the two

FIG. 8. GRANITE OBELISK IN THE MISSOURI BOTANICAL GARDEN NEAR THE MUSEUM—in honor of Thomas Nuttall.

being sent by the American Philosophical Society. The two arrived at St. Louis on March 24, 1834, on the steamboat *Boston,* from Pittsburg. They started from St. Louis, going on foot to the point of rendezvous at Boonville, Mo., where they joined the Wyeth party. The brief period while they went on foot from St. Louis to Boonville is the one which concerns us at present. Unfortunately the season was so early that Nuttall found but few plants in bloom.

The expedition ascended the Missouri River to the headwaters of the Columbia, and then followed that to its mouth. When winter came on with our travelers on the Pacific coast they took passage for the Sandwich Islands, where they arrived January 5, 1835. Here

Nuttall remained for two months collecting plants and sea shells upon the different islands. He then separated from his companion and sailed for California. He spent most of the spring and summer upon the Pacific coast and then returned to the Sandwich Islands, where he embarked upon the same vessel that Dana was serving his "Two Years Before the Mast," to come home by way of Cape Horn. He arrived at Philadelphia in October, 1835, and settled down to study his treasures. For several years he worked thus and published two important memoirs. At Christmas, 1841, Nuttall went back to England, where he resided the last seventeen years of his life. This was not from choice, but because of the conditions under which an estate was left to him by his uncle, requiring him to live in England nine months of the year. He used his ample grounds for growing rare plants. Just previously to leaving the United States he wrote a supplement to Michaux's "Sylva." In the preface his wanderings were outlined. He returned to America but once, when he took the last three months of 1847 and the first three months of 1848. At this time he studied the plants brought by Gamble from the Rocky Mountains and Upper California, and published a paper upon them. His death occurred on September 10, 1859, resulting from overstraining himself in opening a box of plants.

Torrey and Gray dedicated a genus of the Rosaceæ *Nuttallia,* to this prince of scientists.

Henry Shaw has honored him by placing a small obelisk of granite near the north end of the museum building in the Missouri Botanical Garden, with the following inscriptions: on the north side, "In Honour of American Science," and on the south side, "To the Memory of Thomas Nuttall, born in England 1786 and died September, 1859. Honour to him the zealous and successful naturalist, the father of western American botany, the worthy compeer of Barton, Michaux, Hooker, Torrey, Gray and Engelmann." He also placed over the entrance of the main greenhouse in the Garden three busts: that of Linnæus in the middle, and those of Nuttall and Gray on either side.

Although Nuttall explored the Missouri country on two different occasions and worked in Arkansas, he seems never to have published any considerable list of plants found by himself near St. Louis.

(*To be continued*)

THE ART OF BLEACHING AND DYEING AS APPLIED TO FOOD

By Professor E. H. S. BAILEY
UNIVERSITY OF KANSAS

AT last the time seems to have come when the public will have to choose between those food products which from their beauty of coloring or their superior whiteness appeal to the eye, although they may be of doubtful wholesomeness, and those foods which are in their natural state, and have not been "processed" to make them appear better or more desirable than they really are.

That we are becoming rapidly educated in matters that pertain to pure food there is no doubt, therefore those who are nearest the sources of information and who have the opportunity to study the action of foods upon the system may direct public opinion in the right channels. Thinking people always "want to know," even if they are not always quick to overcome prejudice and *do* what their judgment indicates is the best.

While we should be the last to attempt to retard the development of taste for the beautiful in coloring as well as in form, it is time to consider seriously what is to be the outcome of "carrying out the color scheme," in the parlance of the society reporter, in the domain of foods whose function is to nourish the human body.

For the past two or three years there has been a protest, in the more progressive journals devoted to hygiene and pure foods, against the bleaching of foods and the addition of color. This coloring has too often been practised to give the food a better appearance, and we regret to say, to simulate an article of better quality. We are now at a point where the people will have an opportunity to show by their support of existing legislation whether they are ready to take advanced ground against bleached and artificially colored foods.

While for hundreds of years bread made from a good quality of wheat was considered good enough, within the past few years a demand has arisen for white bread. If this notion is analyzed it will probably appear that it goes back to the time when a cheaper bread was made from rye flour or from badly milled wheat flour. Perhaps one reason for the dislike for a dark flour was that its use would indicate that the housewife could not afford a higher grade of flour. No doubt the beauty of the white loaf, with its rich brown crust and fine even texture, also appealed to her. The fact that starch was a comparatively cheap food, and the proteids which made the flour yellow was an expensive food, and that the bread made from the dark flour had a more delicate flavor, was lost sight of in the desire to have a " nice, white " bread to set before her guests.

But the conditions of living have changed, and now most of the bread, especially for the dwellers in the city and village, comes from the bakery. Now it is the baker who tries to fill the demand for a white loaf. With this demand comes naturally enough the effort to get a cheap flour that will make white bread, and the advent of bleached flour into the market.

That this flour is usually bleached by chemicals, just as much as your straw hat is bleached by sulfur fumes, and your sheeting is bleached by " chloride of lime " in the bleachery, is covered up by the statement that the flour is bleached by electricity. Electricity would not injure food, surely! There is no statement, however, that by the use of electricity both nitrous and nitric acid fumes as well as oxides of nitrogen are developed, and that they have, as Professor T. H. Shepard has recently shown, a powerful antiseptic action and actually retard digestion for a longer or shorter time, dependent on the strength, the action of ferments existing in saliva, in the gastric and in the pancreatic fluids. If this is true how can the product do otherwise than retard digestion?

Another phase of the bleached flour question is that this process is used to enable the miller to put on the market a larger per cent. of white flour than he otherwise could, and, of course, greatly to his advantage. This bleached flour is then plainly misbranded unless it bears the label " artificially bleached." Then the customer can purchase this chemically treated flour if he thinks best.

While discussing the use of a bleachery in the preparation of foods, what about the use of sulfur fumes in drying fruits, on the large scale? Is it not possible, the careful housewife inquires, by using a little more care and better stock to dry these fruits without the use of sulfur, or at least with the use of an extremely small quantity? It is true that the dried product may by its color suggest the article that our grandmother used to prepare on the farm. After all, was that so very objectionable, and was the flavor of a dried apple pie made from fruit that had not been bleached and processed until all flavor was gone, so very disagreeable that we did not ask for another piece?

Since the people possibly had the idea that white asparagus was better than green, and that a light-colored sweet corn was more agreeable to the customer than that having the slightly yellow color which nature had given it, the manufacturers began to bleach these products with sulfites in the process of canning. This was in deference to a supposed demand, but the fact that the sulfites might injure the flavor and lower the value of the food from a dietetic standpoint, was entirely lost sight of by the packers.

That much of the food still on the market has been badly spoiled by the art of the colorist, as well as at the bleachery, goes without saying. It is necessary to mention only a few of the foods that have been mistreated in this way. Maraschino cherries are sometimes first bleached and then dyed with coal-tar colors, like a piece of dress goods, any color to suit the prevailing style. Tomato catsup has to bear the burden of sometimes containing much of the refuse, peelings and inferior fruit of the cannery, preserved, it is true, by benzoate of soda, but brought up to the brilliant color desired, by the liberal use of aniline colors. We find it hard to resist the suggestion that in some of these products color is added to conceal inferiority. The best tomato catsup, however, is not made after the receipt mentioned above.

Within the last two or three years artificial color has not been as abundantly used in jams and jellies as formerly, thanks to the provision in the laws of most states, that the constituents of the product must be plainly stated on the label, or the goods would be condemned as misbranded.

Now-a-days you can actually buy ground mustard of good quality that has not been colored yellow with turmeric to cover the inferiority of an article of low grade. Since lemons happen to be yellow, the manufacturers of the extract have thought it allowable to make a weak alcoholic solution of the oil of lemon and color it yellow with a coal-tar dye so that it might appeal to the eye of the purchaser, who, of course, does not investigate by removing the cork and tasting the material. It was a serious fraud upon the consumer. Fortunately, however, at the present time, the people are becoming educated so that there is a demand for an almost colorless extract of lemon, of standard strength. They were no doubt surprised to learn that it did not have to be yellow to be good.

Not long ago the author had occasion to examine a can of French peas (petits pois). They were of a brilliant green color and evidently colored by the use of sulfate of copper. A very tasty brass label was soldered on to one side of the can. When this was removed, however, there appeared in English the statement, "colored with sulfate of copper." Thus the deception practised had been concealed from the consumer.

Bleaching, as carried on by the use of moisture and sunlight, upon the household linen, was apparently a natural process, at least it did not injure the goods. By growing plants away from the sunlight, and thus retarding the growth of the chlorophyl cells, it is possible to bleach the stems and other parts. The natural color of fruit is developed by growth in air and sunshine. We are content with the ruddy glow of the apple, the blush of the peach and the rich scarlet of the strawberry, and ask no artificial coloring to improve them. When these fruits are preserved, or extracts or juices are put upon the market, are we not entitled to the natural product without falsification or adornment? If in the process of preserving the color is not wholly retained, let it go; the flavor of the fruit will not suffer from loss of color, and we soon learn that this change of color goes with fruit preserved in that particular way. The manufacturer prepares only what he believes is demanded by the people, so, after all, the consumers must indicate whether they want artificially colored food or not.

In regard to the artificial coloring of ice-cream, jams, jellies, preserves, gelatin preparations, canned fruits, vegetables, extracts and all foods that have heretofore been colored, the safest position is to demand that they appear on the market without the so-called "improvement," by the art of the color manufacturer, no matter how skillful he be. In this way only are we assured of the quality of the article and its freedom, from this source, at least, from injurious ingredients.

MR. ROOSEVELT'S OPPORTUNITY AS PRESIDENT OF A UNIVERSITY

By Professor DICKINSON S. MILLER
COLUMBIA UNIVERSITY

As one grows older one grows weary of mere generality and abstraction. It would be easy to expatiate at large in this article on the ideal of American universities and the best work that could next be done for them. That, or some of the elements of that, are my subject. But one may well reach out, in this thin medium of idealism, and catch at anything that has more body and more instant meaning. The name of Mr. Roosevelt has come into mention in connection with the leadership of four American universities. There is no evidence whatever, so far as I am aware, that Mr. Roosevelt himself would seriously entertain such a project; and definite announcement has been made of plans that appear to conflict with it. But there is time in store, and universities not a few. In any case it happens that this particular public character serves as no other illustration could to give point to certain suggestions about university life. The human illustration is too helpful to forego.

These suggestions relate, first of all, to the nucleus of the American university, the "college." As compared with all other departments, this part of the institution is in a plight all its own. It suffers from a comparative lack of motive. We have most of us remarked the difference in a student's work when he passes from the college to a professional school. When that step is taken, and the need of a living, the chance of gain and success come home to his daily work, the change in many cases stirs for almost the first time a youth's profound intellectual repose. Machiavelli is right in observing that fear is commonly a more powerful motive than love. At all events the fear of poverty is more powerful than the love of "general culture." To make the balance even, the motives of interest and attraction on the latter side need to be discerningly reinforced. The problem is psychological. Can it be said that in the circumstances of undergraduate study at present there is much to invest the things of the intellect with glow and fascination for average minds? Any one who has talked with students about their election of studies notices that after some experience they will often choose not from the comparative interest of the subject but from the comparative interest of the teacher. Admiration and imitation are amongst the most potent of all formative forces. A young man, whether he knows it or not, wants a hero. This want may of course be supplied for him in very varying degrees and equivocal manners. But at all events he has an eye for such diverse points in his companions as physical prowess, genial manner, wit, leadership, distinction of air, some of the best parts of character, wealth or money-making power—not to mention the grand item of elegant and gentlemanly attire. Now a professor, to the undergraduate, is a more or less amiable "grind" of riper years. Riper, but still unluscious. He is in the center of the undergraduate's vision for an hour, let us say, three times a week; mainly under that lecture-system which, as it has been with fine accuracy stated, enables the student to lean back and observe at perfect leisure the personal peculiarities of the instructor. The student is to have a career in time himself, and dimly or consciously he looks forward to it. A general, a statesman, an explorer, an orator, a sportsman, a successful lawyer, an archmillionaire—or even an artist—is by no means without interest for him; but the amount of *Lebensherrlichkeit* represented in a professor does not reach what psychologists call the threshold of his appreciation. This fact colors the feeling of his class. To teach young men like themselves might appear a high calling were it not that to bore young men like themselves seems a dingy trade.

Now it must candidly be confessed that the student's view is not without some elements of justice. A profession whose chief function is performed in the classroom and which yet so often leaves the classroom-hour on the whole such a lackluster memory does forfeit its claims to some portion of the glamour that might perhaps ideally attach to it. Not that the memory should be simply of entertainment. There is much in the saying of Epictetus that the lecture-room should often be, like a surgery, rather a place of beneficent pain than of pleasure. What is important is that it should be a scene of effectiveness.

In 1881 Phillips Brooks, then preaching at the full tide of his influence, was invited to become chaplain and professor at Harvard. Efforts were made by men of weight in Boston to induce him not to quit his work in that city. Mr. John Long, then governor, wrote in the course of a letter since published:

> The Harvard boys do not need you so much. They have everything already. If they develop some wild oats, yet the general surroundings of their college life lead them to higher opportunities and standards sooner or later.

Mr. Henry Higginson wrote:

> You can't work on those boys in the same way, simply because they are at the questioning, critical, restless age. The worst of them are not bad, but frivolous or idle-minded. The best of them are seeking for the truth everywhere,

> and had better seek by themselves. Let them ferment. Of course you can help many a restless spirit, when he *wishes* to be helped—but you can do it as well here as at Cambridge.

Mr. Robert Treat Paine wrote:

> College life is full of fun and froth and frolic and frivolity and scurrility. It is acutely critical. It turns into sport everything, sacred and profane. Life is free there first—full of joy and sparkle, full of study and sports, absorbed and preoccupied. Entire absence of variety in experience; death, marriage, children, business, failure, sickness, suffering, danger, all that makes adult life so full—none of all this enters the life of the student. . . . Surely this is the least impressible part of life. It is not responsive, it has no magnetism in it.[1]

That the best youth seeking truth in a university "had better seek by themselves" and that youth (at least if at college) "is the least impressible part of life" are doctrines of precisely the tendency that occasions the present article.

It would be grossly unfair to take these remarks, dropped as they were in the course of a heartfelt argument for the surpassing value of Phillips Brooks's work in Boston, as though they stood for the whole thought or final attitude, on the subject, of the writers' minds. And no doubt Brooks solved his personal problem with a wise caution in refusing to leave his own rich field for one untried. What the letters completely miss, however, is the fact that the extraordinary conjunction in college youth of the freshly acquired faculties of manhood with freedom from manhood's burdens and chilling memories is not a mere hindrance to the great leader but an extraordinary opportunity. Appreciation of certain things has not come in youth because experience of them in oneself has not come; but the liberated energies are ready for ardor and enterprise and generous impulse as those of the burdened and hard-worked can never be. Have we not heard of something called youthful enthusiasm and of something called youthful idealism? A writer of genius has described youth as "cold and pitiless." That is, though it *sees* (with what sharpness!), its sympathies fail much, because it has not felt for itself such things as are behind the face it sees. That is the sole reason, for the youth *plus* the experience (might it be remembered?) is the material of which the less "pitiless" man is made. No one can long observe the studentry of a college, watching them in their sports and crises, without seeing a fire ready to be kindled, waiting only for the spark. If college youth are cold on their more serious side it has at least something to do with the fact that so many of the minds with which they come in contact are absolute non-conductors of heat.

It will perhaps be clear at this point why I can not forego the human

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[1] Allen, "Life of Phillips Brooks," Vol. II., ch. 10.

illustration of my meaning furnished by Mr. Roosevelt. I remember a lady of exquisite perception saying that for twenty years and more she had lived near a great university and that she looked to see there in the future "a blaze of impulse." Has there been any one in our history who could kindle "a blaze of impulse" in a community of young men as Mr. Roosevelt could? As a psychologist has remarked, he is a born moralist. And the moral principles he preaches (the fact is often made a reproach to him) are not above the comprehension of everybody; they are what were called long ago "the great commonplaces of morality." He may regard the disdain of fastidious minds on this account with much equanimity. Life is indeed "a rediscovery of copy-book maxims." The somewhat slender hold that born moralists for the most part have upon the young man is due to their not being rich in natural life and in the raw material of human nature. There is just a touch of the astringent about them; a taste of "moralic acid." In other words they are not quite the type that he spontaneously admires. The combination in Mr. Roosevelt, which for us and in its degree may fairly be called unique, is that of the moralist and the natural hero of average minds. It is something to have in one person the intense preacher and him of whom every boy would say (as the poet said of the "rough-hammered head—great eye, gross jaw and griped lips" of another) "What a man!" At all events the boy would say it if not prompted otherwise by having overheard the acidulous talk of alienated elders. The strong hold of such a leader on his college men would be maintained in part by addressing them. It is something to have a speaker who is also a doer. That he is without grave faults Mr. Roosevelt himself, I cannot help fancying, is the last one who would pretend. That his intention and his nature are not good no unentangled person who has watched him long and closely can easily be found to testify. The general verdict of such is that of Mr. John Morley: "A man and a good man." We have had hasty and crude statements from him on subjects where he was not at home; we have in general ceased to have them when be became at home on those subjects. We have had unduly heated language from him under intensely provoking circumstances; a conductor of heat has the defect of his quality. We have had plentiful charges against him of inaccuracy and worse. The statistics respecting charges of loose statement against responsible executives, if they could be gathered, would be interesting and to many surprising. Decision in each case is possible to no man without searching investigation. The statistics in regard to actual accuracy in general would perhaps in each case surprise none so much as the one they concerned. I would not condone looseness in such matters; much to the contrary; but I would remind the accusers of themselves and of cautious justice. Whether his statecraft has on the whole been correct is a political question, out of place here. No doubt there are those who would try to punish him for deviations from the public policy they have desired by opposing him for a non-political post. With such animosity I shall not contend. We know that in the vast range of remote appointments Mr. Roosevelt's selection of men for places not the highest has often been bad. We know that near home, in his cabinet and otherwise, he has surrounded himself with some of the most capable. His desire and his enthusiasm for men of power, his absolute freedom from the jealousy that would surround itself with lesser and merely instrumental men, his generous friendship and laudation, are for our present interest amongst the traits that promise most.

The chief trait, that on which we have already dwelt, is perhaps best characterized in Walter Bagehot's remarks on Mr. Gladstone as a public speaker:

> A man must not only know what to say, he must have a vehement longing to get up and say it. Many persons, rather sceptical persons especially, do not feel this in the least. They see before them an audience—a miscellaneous collection of odd-looking men—but they feel no wish to convince them of anything. "Are not they very well as they are? They believe what they have been brought up to believe." "Confirm every man in *his own* manner of conceiving," said one great sage. "A savage among savages is very well," remarked another. You may easily take away one creed and then not be able to implant another. "You may succeed in unfitting men for their own purposes without fitting them for your purposes"—thus thinks the *cui bono* sceptic. Another kind of sceptic is distrustful, and speaks thus: "I know *I can't* convince these people; if I could, perhaps I would, but I can't. Only look at them! They have all kinds of crotchets in their heads. There is a wooden-faced man in spectacles. How can you convince a wooden-faced man in spectacles? And see that other man with a narrow forehead and compressed lips—is it any use talking to him? It is of no use; do not hope that mere arguments will impair the prepossessions of nature and the steady convictions of years." Mr. Gladstone would not feel these sceptical arguments. He would get up to speak. He has the *didactic* impulse. He has the "courage of his ideas." He will convince the audience. He knows an argument which will be effective, he has one for one and another for another; he has an enthusiasm which he feels will rouse the apathetic, a demonstration which he thinks must convert the incredulous, an illustration which he hopes will drive his meaning even into the heads of the stolid. At any rate, he will try. He has a *nature*, as Coleridge might have said, towards his audience. He is sure, if they only knew what he knows, they would feel as he feels, and believe as he believes. And by this he conquers. This living faith, this enthusiasm, this confidence, call it as we will, is an extreme power in human affairs. One *croyant*, said the Frenchman, is a greater power than fifty *incrédules*.

This quality is far from the only quality required in an educational leader; but circumstances conspire to give it value in a college. Somebody is needed to make cultivation seem "worth while." Somebody is needed to "lead the cheering" for study, for work. Somebody is needed to offset the snobbish instructor who says (and whose own sympathies are affected by the opinion): "Debating contests are not a thing that the best class in the university takes any interest in." Somebody is needed to make the prizeman just the least bit of a hero amongst his fellows. Somebody is needed to make the keen intellectual blade or wide reader, whether he take academic rank or not, feel his accomplishment to be something more than an overshadowed and unfashionable brilliancy. Somebody is needed to fan the lurking sparks of ardor in the mind. Somebody is needed to make visible to the young eye that invisible war with powers of the air in which the scholar is a man-at-arms and a campaigner. And if this leader is also an athlete and a sportsman, if this leader of work is also a leader of play, the blend can hardly, as things now stand, be over-prized.

For it brings us, in a rough but ready form, in sight of that round and whole education which is the sane ideal. It might even make the sanguine hope to see in an American university ideas current amongst the healthy studentry as one often sees them in Europe. Such a leader would not stop contented with those excellent athletic contests in which, however, a horde of undergraduates sit as spectators while a few harrassed braves perform. He would be likely to remember that the most successful systems of education, in antiquity for example, cared for the bodily training of every individual. One can not imagine his advent failing to make a difference even to "the unexercised and the unwashed."

But the difference made by his advent as regards moral ideal is the least to be forgotten. I will not repeat what is so often truly said about the state of the moral atmosphere in the nation with regard to money. Which are the personalities that really glitter to average young eyes? When a brilliant man of business and of fashion accumulates a vast fortune in his last years by methods believed to be dishonorable and dazzles a city by his social charm, the tasteful splendor of his surroundings, and his business power, when it is commonly said in comment on the tales of his private life that "those men do absolutely anything they like," it is noticeable that even the rumors touching the manner of his death do not entirely check the awe of the young listener.

It is something to give collegians an embodiment of what they feel to be dashing success and national power, wholly untainted in point of honesty and private life; something to have brilliancy and probity undivided.

Of course there may be those who feel that Mr. Roosevelt would come whooping into the still air of study and, being used to mightier affairs, would disarrange nice customs, dishevel sound old proprieties, and step absentmindedly over the college halls. These, however, would be apprehensions hardly worthy of men prepared to stand to their own prerogatives and duties. If Mr. Roosevelt could lend signal aid in education he would hardly dispute that such a task would have its education for himself. And if students delight in his sturdy manhood, it would be a pity that the race of teachers should shudder at his somewhat carnivorous quality and taste for the jungle.

There is, to be sure, a delicacy of tone, a fine and deep cultivation of spirit, a sense of esthetic rectitude in things of detail, that one would gladly see set before "our young barbarians, all at play," in the chief person of their community. The fiery furnace of American public life is hardly the place to foster and finish such a product. Indeed this *fine fleur*—for the truth must be told—does not at present flourish abundantly in American life at all. Our scholarship has largely gone for training to Germany, custodian of the letter rather than of the spirit of culture; and there is something raw in the air at home. But in Mr. Roosevelt's passion for knowledge and for achievement, in the range of a certain information he has in science, history and letters, in the interest and respect he has always shown for the personalities of the men who advance these studies, there is much to contribute toward the first things needful, the foundation of university life.

It is obviously a grave consideration on the other hand that he has had no direct experience, except as a student, of educational affairs. This, however, as it happens, is bound up with the essential qualifications we have been considering. Senator Hoar remarks in his "Autobiography":

> Making all the allowance for the point of view, and that I was then a youth looking at my elders who had become famous, and that I am now looking as an old man at young men, I still think there can be no comparison between the college administrators of fifty years ago and those of to-day. It was then the policy of the college to call into its service great men who had achieved eminent distinction in the world without. It is now its policy to select for its service promising youth, in the hope that they will become great. Perhaps the last method is the best where it succeeds. [And Mr. Hoar notes the distinguished success of President Eliot.] But the effect of failure is most mischievous. Presidents Quincy, Everett, Walker and Sparks administered in succession the office of President during my connection with the Academic Department and the Law School [of Harvard], although Dr. Walker's inauguration was not until later. Each of them in his own way was among the first men of his time. Quincy had been an eminent statesman, a famous orator, and a most successful mayor of Boston. Edward Everett had been in his early youth one of the most famous pulpit orators of the country, afterward a distinguished Member of Congress, Governor of the Commonwealth, Minister to England, and Senator of the United States. He was a consummate orator, on whose lips thousands and thousands of his countrymen had hung entranced.

> He was, what is less generally remembered now, perhaps the ablest and most accomplished diplomatist ever in the public service of the United States. Jared Sparks was a profound student of history, somewhat dull as a narrator, but of unerring historic judgment. . . . James Walker was a great preacher and a profound thinker.

We need not venture to pronounce on Mr. Hoar's preference for good old days. What is notable is the suggestion of the effect of bringing successful men of a high type from the midst of the world, for which the student is destined, and putting them in his formative time before his eyes. The result, in honorable ambition, civic enthusiasm and the influence of large ideas upon the tone of mind, weighs something, it must be admitted, against the chosen man's lack of direct acquaintance with an educational institution and with just this species of administrative headship. The appalling diversity of subjects that a national president must master encourages the hope that he would not fail to respond with skill to those of the president of a university.

This brings us to face the question what, at the present juncture, the largest problems of an American university are. I have been forced, however, to dwell at some length on the justness of my human illustration, and on immediate problems that such a leader would help to solve. Space fails me to discuss certain other and more complex problems in which the putting of precisely such a powerful shoulder to the wheel is equally required. With the editor's permission I will return to the subject next month in a second article. These latter difficulties call for a leader who adds to enthusiasm a long-borne burden of the most trying practical experience. They call for one who, if an idealist, has the best reason to be a realist too.

COMMERCIALISM

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THE pessimistic streak, woven into every man's nature, becomes a broad band in the community when industrial interests are prostrate. During the past year, the men who during prosperous times lived in the solitude of their sorrows have come forth and have found appreciative listeners as they denounce our country's sins and despair of its salvation. For a year they have gloated over the frailties of society, the corruption of politics, the degradation of business morals; they have pictured the gloomy future of a country sunk in materialism, a prey to commercialism; they have sung in minor key of the purer days when a man was counted for his worth, when mere wealth carried no weight, when mind was more than matter, when dishonor was unknown.

Every unprejudiced observer sees that affairs are sadly out of joint and he longs for some mighty surgeon to adjust them; but he sees no ray of hope, no cure for human woes in these jeremiads; he recognizes only the old wailing, the old discord, with here and there a new note to catch the ear of passers-by. It is as old as the race itself. Doubtless poor old Adam thought sadly of his bachelor days, untried by any Eve of speculative temperament. The Prisse papyrus, written during the twelfth dynasty and copied from one of the fifth, carries us back to at least 2500 B.C.; its aged author grieved over the degeneracy of his times and longed for those better days of the past. More than fifteen hundred years afterwards the author of Ecclesiastes, pessimist himself, rebuked querulous men who asked why the older days had been better than these; Greek and Roman literature is full of laments and the poets sang wearily of a golden age, long past and past forever. Our own Washington had little hope for his country as he considered the decadence of public and private honor, the selfish anxiety for advancement and the corruption prevailing everywhere toward the close of the eighteenth century. Yet that was our age of gold, when corporations were unknown, when railroads had not been conceived, when petroleum had not soaked the land with its slime and Wall Street had not come to crush the people's energies.

Commercialism is the superabounding cause of all troubles; a vague something is this term commercialism, eluding definition, but evidently including all that is evil. It is the spirit of business. To denounce commercialism is the duty of every "high thinker"; the defender of business men can rarely obtain fair hearing. If in modest position, he is liable to be treated with mingled pity and contempt; if in responsible position, he is likely to learn that he is biased by self-interest; if a college officer, he is cast out of court at once as a hireling, because at some time or other a business man has done something for the college. The "high thinkers" can be described only by Job's reply to his similarly self-sufficient and equally ill-informed friends—"No doubt but ye are the people and wisdom shall die with you."

These critics of our day in their denunciation of commercialism are merely plagiarists of not very high order. The ancient Persians avoided commerce as a baneful pursuit, fatal to integrity; the Roman held commerce in slight esteem and mocked the gold-worshipping Athenians with the sneer, *Græcia semper mendax.* Yet those peoples, seeing so clearly the mote in their neighbor's eye, were blind to the beam in their own; while they despised the arts of peace they saw no sin in the arts of war, the wiles of diplomacy or the treachery of conflict. One can understand the Persian's position, but it is difficult to understand how an educated Roman could fail to recognize that his nation's culture had been absorbed from Grecian colonies on the Italian coasts. The Roman contempt for merchants was ingratitude matched only by that of some would-be philosophers of our time. For, be it remembered, civilization and commerce are twin sisters, never antagonistic, but always advancing hand in hand.

The world's greatest debt is due to civilizations born on the Nile and on the Euphrates, six or seven thousand years ago, both of them commercial. The Babylonians, inhabitants of the lower Euphrates area and intermediaries of commerce between India and the Mediterranean peoples, attained to a civilization prior to 2500 B.C. apparently comparable to that of Great Britain in the eighteenth century. It was marked by studies in science, by literature, by a noteworthy system of laws and by prosperity of the common people as well as of the rich. It dominated the whole of southwestern Asia and by 1500 B.C. its language had become that of the court even in Egypt and Asia Minor. When the course of commerce was diverted to the Red Sea and Alexandria, the glory of the Euphrates departed, to return only for a little when commerce revived under the caliphs of Bagdad.

Close intercommunication and the interchange of products along fifteen hundred miles of the Nile, conjoined with a vast caravan and sea trade with Arabia, Asia Minor and Mesopotamia, as intermediaries of the whole region drained by the upper Niles, led to the development in Egypt of a civilization whose remains are even more notable than those along the Euphrates. Its character appears from the architecture, the engineering works, the agricultural operations as much as from the literature and the science. When one views the ruins at Karnak and considers that the rock on which the Egyptian sculptor labored is one of the most intractable granites known, he marvels at the sculptors' skill as much as he admires the genius of the architects who planned the gigantic structures. If instead of granite from Syene the material had been soft Pentelican marble, the dainties of Grecian architecture and the grandeur of Egyptian might have been united at Karnak.

The Greeks competed long with the Phœnicians for control of Mediterranean trade; their colonies were in Asia Minor, Italy and Sicily as those of the Phœnicians were in northern Africa and the west. When Psammetichus ended the seclusion of Egypt by opening her ports and by enlisting Greek mercenaries into his army, travelers from Grecian colonies found their way thither, gathered fragments of Egyptian philosophy, literature, science and art and carried them back to their own land to be fused with similar fragments from Arabia, Mesopotamia and Phœnicia, just as seventeen hundred years later the Crusaders brought home with them the knowledge of oriental civilization. The philosophy and literature of Greece originated in her commercial colonies. When Athens and her immediate allies, after the Persian war, wrested commercial supremacy from the Phœnicians, the Piræus was enlarged and Athens became at once the commercial and the intellectual center of the world. Then, the art and thought of other lands unfolded through Grecian genius into wondrous proportions—with a background of no history and a foreground of the dark ages, it seemed to be a veritable Melchisedec, without ancestor, without descendant. Only within the last thirty years has its true place been determined.

Those whose energies are expended in bitter sneers against commerce either forget or ignore the truth that Athens was preeminently commercial. They seem to think that the city was enveloped by an atmosphere of pure intellectuality amid which the necessary merchants moved in a state of semi-asphyxiation. Some years ago, a writer in a religious paper, lamenting modern degeneracy, asserted that in Athens the street boys competed in making verses whereas in New York the street boys play marbles. No doubt some Athenian boys engaged occasionally, just as some New York boys do now, in the possibly lofty game of verse-making, but from what is known of the Athenians and of the Greeks from the earliest times to our own day one may suppose with more probability that the Athenian boys' favorite sport was that of matching small coins. Commerce was never disreputable in Athens; Aristotle is said to have been an apothecary, and Plato an exporter of oil. That city at the time of her greatest intellectual splendor can be compared in modern times only with cities such as London and New York. Long centuries hence there will be men who too will grieve over decadence of the race and the love of pelf. They will hark back to the days when London, Boston and New York produced such marvelous intellects.

That commerce brings wealth and that wealth brings luxury with eventually moral and physical decadence are propositions which, separately, admit of no dispute; but they must not be united, for wealth, not commerce, is responsible for the luxury and in part for the decadence. Babylon, Tyre, Athens, Corinth and Alexandria were commercial cities; each, after reaching the zenith of prosperity, showed that decay which so delights some students. But the morality of Persia sank to wretched depths in the time of Xerxes, when the vast wealth of many lands had been gathered by conquest; Nineveh, alike commercial and warlike, was enervated by luxury in the time of Assurbanipal and soon sank into obscurity; while commerce-despising Rome, enriched by the spoils of war, became, even before the Christian era, a veritable sink of moral pollution. At the same time one must note the all-important fact that though luxury eventually brings about decadence, still its first fruits among commercial peoples have always been intellectual and esthetic growth. The grandeur of Egypt attained its maxima under luxurious Amenemhat, Thothmes III. and Rameses II.; luxurious, unwarlike Assurbanipal gathered the literature of ancient Babylonia and of Assyria into his vast library at Nineveh; luxury-loving Athens and Corinth, not luxury-hating Sparta, produced the Grecian sculpture and architecture; luxury-loving Bagdad and Cordova encouraged literature and science and, in Spain, built the Alhambra.

Commerce brings wealth; the possession of wealth leads to luxury; a luxurious community is corrupt. This, according to moralists, is the sequence, and the belief in its truth is of such hoary antiquity that to contest it is as though one doubted the law of gravitation. But the belief only proves poor human nature's readiness to shift the blame for its inherent weaknesses. The corruption of a wealthy community differs from that of a savage community not so much in kind as in degree. The clerk who pilfers from a cross-roads shop is in the same class with a bank officer who "appropriates" several millions of dollars. The difference is only in opportunity. Dishonesty in one form or another is so much part of human nature that its spores, so to speak, are breathed out into the atmosphere. A reformer, aggrieved by its constant reappearance, is as unreasonable as the amateur gardener who is perplexed by reappearance of weeds in his carefully tended garden. There will always be enough to give occasion for the philosopher's tears, enough to give a dull background to any picture; but that is not to say that when one compares this day with that of our fathers he must find reason for renewed sorrow.

Man can not pass at once from savagery to civilization; that change has been in process for millenniums and still it is far from complete. Equally slow is the passage from primeval grossness to ideal purity. The golden rule is a fundamental principle of the ethnic religions as much as of Judaism and Christianity. During more than three thousand years it has been urged as the rule of life, but war and rapine still fill the pages of man's history; yet it has not been ignored and, with the passing centuries, its hold on mankind becomes stronger. In the business world, each period of advance ends abruptly in a storm of stress and panic, by which all seem to be prostrated; but the recession never returns to the previous stage. So in the moral world, the tide flows and ebbs, but each rise advances farther up the slope than did the last—as much in this land as elsewhere.

Three years ago the community was startled by revelations of mismanagement in the great insurance companies and the matter was more than a nine days' wonder. Pulpit and press vied in condemnation of the wicked men. Yet the culprits had not looted their companies; they had not decreased the security of the policy-holders; they had merely utilized their positions for personal gain, making themselves partners with their companies in profitable ventures; they had been guilty of imperfect consecration to the interest of their trust and had shown what wholly unscrupulous men could do. One can well imagine the perplexity of a resurrected magnate of sixty years ago, when told of this crime. Surely he would think that times had changed. In his day such conduct would have passed unrebuked, nay, it might have been commended, as the companies had profited by the transactions. It is rebuked now because there is at last a public conscience which compels respect.

Even politicians recognize this and are not slow to turn it to their own advantage. Only a little while ago, the operations of a syndicate in connection with a western railroad were the subject of governmental investigation; the so-called exposure filled columns of the papers, was made almost a national issue, being utilized in political strife. Yet the whole transaction had occurred in full view of the public without attempt at concealment or deception. The syndicate which owned the property almost outright was charged with increasing the capitalization without equivalent expenditure, but there was no evidence that any one had suffered by the operation, though clearly some one had profited. Whether or not there was any wrong in this transaction is difficult for a layman to discover; but as presented in *ex parte* form, the matter sufficed to justify the astute politician's appeal to the public conscience. The existence of the wide-spread sense of justice secures attentive hearing to critics of "commercialism" when they denounce the methods of corporations; *ex parte* statements by prosecuting attorneys and statements by magazine writers are accepted as embodiments of undisputed fact. The development of a public conscience has not been accompanied by equal development of the judicial temperament.

Whether or not the methods employed by some corporations in efforts to overcome competition measure up to the popular conception of the golden rule is not open to discussion. In the original form that rule is "Thou shalt love thy neighbor as thyself"; and it would seem that the obligation is on all alike. But the popular conception is that the command is binding only on the corporations and that all individuals in the community are "neighbors." Yet corporations are merely copartnerships, so that in their case, as in the case of the individual, the standard of the rule is the love of one's self, which brings into consideration the question of self-preservation. A man is justified before the law if he take the life of another to protect his own or that of any under his charge; he may take life to protect his property; equally in business affairs, a man is justified in doing things for self-protection, which under other conditions would be unjustifiable.

The owner of a cross-roads shop, who has built up a good trade by close attention and honest dealing, would be thoroughly justified in bitterly antagonizing a rival who had secured the old stand that he might reap where he did not sow. If, however, success have made him negligent so that he serves his community indifferently, he should not complain against the invasion; he alone is responsible; he had thrown away his estate.

Both conditions are familiar. Corporations find themselves at times as the old, still energetic shopkeeper, fighting to hold his own; at others, as the sturdy newcomer invading an area occupied by sluggish men, satisfied with small business and large percentage profits. To illustrate.

Several men competing in the manufacture of some product combine, reduce working expenses and with the money thus saved secure competent scientific aid for improvement of methods. New processes are discovered, cost of production is decreased, waste is prevented and by-products are utilized; the result being eradication of rule-of-thumb competitors while the innovators gain control of the business to their own great profit and to the great advantage of the consumers. They remain incessant in efforts to better processes and to make new industries; but eventually the earlier patents expire. Other men, in view of this, have been investigating and have discovered improvements in methods, to become available with expiration of the early patents.

The men whose foresight made possible the vast extension now see their property placed in jeopardy by means of their own processes, discovered at great cost, and they struggle to retain their own. Under such circumstances the importance of the golden rule is made very prominent, each side charging the other with neglect; yet, whatever may be the shortcomings of the older manufacturer, one must concede that the newcomer usually regards himself as the neighbor and therefore unfettered.

On the other hand, combinations have invaded areas regarded by others as their preserves; and here is involved the question of a man's natural right to secure a living easily at the expense of his fellows—that which is involved in the department-store problem. A corporation, under heavy fire recently, was charged with the crime of owning its retail shops, while selling its goods to retailers. Yet any self-respecting man would resent an effort to prevent him from selling his own goods according to any one of the approved methods. If a manufacturer, on large or small scale, choose to establish his own retail store or stores, no one has any right to complain—it matters not what the goods may be, cigars, shoes, oil or meats. In any event, such a method would be advantageous to the greater number by leading to division of middlemen's profits between maker and consumer.

The cry in many quarters is for unrestricted competition in trade, but recent events prove the cry to be utter hypocrisy. In one state a suit for ouster was brought against a corporation because, owing to competition, it sold its products more cheaply in some localities than in others. A similar suit was brought in another state because the company had set its prices so low for some years that no competitor could do anything in the region. Evidently the only free competition desired is that which would remain after binding the one on the ground—an open market for the newcomer. The opponent of that company is anxious to have the government enter into conspiracy with him to increase the cost of necessaries of life.

That conditions in commercial circles are not ideal is beyond question—they are far from ideal in any circles and they will never be otherwise until man has passed away and has been succeeded by a superior race of beings. But one must recognize that very much of the wickedness upon which writers descant so vehemently consists merely in so-called evasion of law. It is certain that serious dangers to the commonwealth are inherent to vast combinations of capital; and it is equally certain that imperfect legislation in the past opened the way to abuse, of which selfish men have not been slow to avail themselves. Some form of governmental control is necessary to prevent excess. All recognize that a corporation, being a creature of the law, does not possess natural rights as does an individual; but once created it has the rights conferred on it and in all legislation those rights must not be forgotten. Unfortunately, most of the legislation against combinations is the offspring of men unfamiliar with the interlacing of business interests, so that while it may correct or destroy one wrong it creates a dozen others. Too often the statutes make criminal that which is ethically just. Such statutes, it is true, are the law of the land and every good citizen should obey them as far as in him lies. But the law requires him to obey the letter, not the spirit, for no created being can fathom the depth of the spirit or divine what was in the mind of those who conceived them. If the laws prove to be ineffective, the fault is not in the citizen, but in the ignorance of the lawmaker. Our country owes a debt of gratitude to those lawyers who, ascertaining the exact letter, have guided our great corporations through the labyrinth of statutes and enabled them to avoid pitfalls. Had not a merciful providence provided those lawyers, the country would have been the loser—and the statute-makers, most of all, should be grateful, for the evils of their work have not recoiled upon their heads. Controlled in most instances by men of great sagacity, combinations have lessened the cost and increased the output of manufactures while bettering the wage-earners' reward.

Assertion that the existence of vast combinations of capital is the surest foundation of national prosperity is, for many, evidence of insanity or of dishonesty or of both. Yet no generalization could be more nearly true. A single illustration suffices.

When the business depression following 1873 ended abruptly in 1879, the iron and steel industry was wholly unprepared for the new conditions. A great part of the furnaces were out of blast and the metal required at once by railroads and other interests could not be supplied. Great combinations were unknown, there were many concerns—there was that unrestricted competition which some regard as Utopian. All had suffered severely during the depression and the few concerns still in operation set themselves at once to make good their losses. A veritable scramble for profits ensued on the part of both employers and employed. The price of pig iron increased so rapidly as to pass the point where the moderate tariff became unimportant and foreign makers unloaded their stocks of metal on us, glutting the market and prostrating the pig-iron industry. Meanwhile the cost of manufactured products had gone beyond what the "traffic could bear" and prosperity came quickly to an end.

The conditions of 1879 were repeated in 1899, but the outcome was wholly different, for the iron and steel interests were concentrated and the business was controlled by a few vast combinations. No one of them could increase the price without consent of all, but any one could hold the price down against opposition by all its rivals. The leading concerns, mindful perhaps of 1879 and 1880, determined that prices for manufactured products should not exceed a fixed scale, more being ruinous—and they maintained that scale in spite of greatly increased cost of pig metal. The result was almost uninterrupted prosperity until 1907, when the whirlwind of senseless attacks on corporations, as such, swept over the country. Even now the prostration is unlike that following 1873 and 1893. The great organizations, during their prosperity, laid aside a surplus for evil days. When disaster came a year ago, there was no wild rush to dispose of accumulated stocks; there was no crash in prices; there was no wholesale reduction in wages. While there has been want in the distributing centers, the country at large has known no such wide-spread distress as that which followed former business disasters.

But the wisdom of our rulers has made consolidation or combination of competing interests unlawful. A New York judge recently decided that consolidation, even though advantageous to the public, is illegal in case it involve stoppage of competition. If two grocers on opposite corners have waged war until both are threatened with bankruptcy, their friends would advise them to reach an understanding, might advise even union and the closing of one shop, that by reducing expenses and selling at a fair profit they might gain an honest living. Yet there is reason to believe that such a course might be adjudged contrary to law, being a conspiracy to increase cost of necessaries of life. Their customers would certainly express that opinion.

This is no exaggeration. Residents of New York City were well satisfied some years ago to buy coal at $4.50 per ton, wholly indifferent to the fact that the anthracite companies were engaged in reckless and unjustifiable strife. When the contest had gone so far that bankruptcy seemed inevitable for some of the companies, the officers awoke to their responsibility to the helpless stockholders, whose interests they were to guard. An agreement was made to mine no more coal than the market demanded and to charge a price which would enable them to pay fair wages, to meet their obligations and to earn interest on their investments. At once the customers were filled with indignation, the papers denounced the oppressive "coal barons" and agitation began which eventuated in legislation so drastic that, were it sustained by the courts and fully enforced, the companies, deprived of rights guaranteed them half a century ago, would be forced into bankruptcy and millions of persons would be plunged into misery. There is a strong popular feeling that live and let live is the only true policy; but clearly the popular interpretation of this doctrine is wholly one-sided, the policy must favor the consumer alone—in forgetfulness of the fundamental principle that all interests are mutually dependent, that one can not suffer alone; all must share.

The day of small things has passed; railroads, telegraphs, express steamships have changed the units of competition from individuals to nations. If Great Britain, Germany and the United States are each to have a fair share in the world's markets, they will do so only through the sagacity of men controlling the policies of great combinations. Even in our own country, the territory is so vast that, to secure internal prosperity, such combinations are essential in every department of activity, manufactures, colleges or transportation. Petty rivalries of neighbors are too costly, too wasteful; duplication of plants is folly, when by a slight increase in some portion of one it can be made to do the work of both. In view of this, men should recognize that *vox populi* as expressed in legislative enactments is not necessarily *vox dei;* that right can not be converted into wrong by the vote of an accidental majority; that exact obedience to law is not sin.

FOREIGN ASSOCIATES OF NATIONAL SOCIETIES. II.

By Professor EDWARD C. PICKERING
HARVARD COLLEGE OBSERVATORY

A HISTORY of the sciences and of scientific men during the last two centuries, by M. Alphonse de Candolle, was published in 1873. A table is given showing the foreign membership in various societies for the four epochs, 1750, 1789, 1829 and 1869, at intervals of about forty years. Since another interval of forty years has now elapsed, it may be of interest to compare the results with those at the present time. The earlier part of Table I. is taken from M. de Candolle's volume, page 176. The country is given in the first column. Scandinavia includes Sweden, Norway and Denmark. Austria includes Hungary. Russia includes Poland. Spain includes Portugal. A few scattering names are similarly included. The percentages of membership in the various countries are given in the following columns, the year being given in the first line of the headings and the letters designating the various societies being given in the second line. F, B, G and R denote the Institute of France, the Royal Society of London, the Royal Prussian Academy of Sciences and the Imperial Academy of St. Petersburg, respectively. Since only foreign membership is included, dashes are inserted in the case of home societies. Thus, in the first line, dashes are inserted in the column headed G, since no Germans could be foreign members of the Prussian Academy.

Some of the results to be derived from Table I. will be found in

Table I.

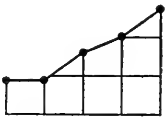
Country.	1750			1789			1829			1869				1908			
	F	B	G	F	B	G	F	B	G	F	B	G	R	F	B	G	R
Germany	14	15	—	8	14	—	36	27	—	42	45	—	45	33	39	—	37
France	—	46	43	—	36	33	—	38	41	—	33	38	23	—	18	21	18
Great Britain	17	—	12	15	—	...	29	—	14	29	—	26	16	20	—	17	16
Scandinavia	14	1	7	10	10	3	7	8	12	1	4	9	5	11	9	17	8
Italy	20	14	12	15	16	19	10	8	18	4	2	3	...	7	9	7	8
United States	...	...	...	3	2	3	1	...	...	...	2	3	8	7	11	10	4
Austria	...	...	...	3	...	...	1	2	...	...	...	...	...	3	2	17	5
Holland	6	7	10	10	3	8	3	2	...	...	2	3	...	7	7	7	...
Russia	...	1	2	8	3	6	1	2	8	10	2	6	—	5	2	2	—
Switzerland	17	12	12	13	10	19	7	8	6	9	8	8	5	3	2	...	3
Belgium	...	...	...	3	3	...	3	...	2	4	2	4	1	3	...	2	1
Spain	11	4	2	13	4	8	...	4	...	...	...	...	...	1	...	...	...

Table II. The country is given in the first column, as in Table I. The percentages of the entire membership of each country in the years 1750, 1789, 1829, 1869 and 1908 are given in the next five columns. As the tenths of a per cent. are omitted, the sums are not exactly 100. The seventh column gives the difference found by subtracting the numbers in the second column from those in the sixth. If positive, it indicates an increase, if negative, a decrease in membership during the one hundred and fifty-eight years. These twelve differences may be divided into three groups of four each, including the countries showing a large increase, those remaining nearly the same, and those showing a large decrease. The results are given in the last three lines of the table. It may now be of interest to compare the results of this discussion with that published in THE POPULAR SCIENCE MONTHLY, LXXIII., 372. A list is there given of the eighty-seven persons who were foreign associates of two or more national societies, in 1908. The percentage of these members and of their membership is given in the eighth and ninth columns. They are derived from Table III. of that paper. The tenth column gives the percentage of the eighty-seven members who were born in each country.

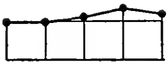
TABLE II.

Country.	1750	1789	1829	1869	1908	Diff.	M.	S.	B.
Germany	12	9	24	35	31	+19	34	35	32
France	36	29	30	25	16	—20	14	14	13
Great Britain	12	6	17	19	15	+ 3	15	17	17
Scandinavia	6	6	7	4	10	+ 4	10	8	11
Italy	12	14	9	2	7	— 5	3	4	3
United States	...	2	...	2	7	+ 7	7	8	3
Austria	...	1	1	...	6	+ 6	5	5	3
Holland	6	6	1	1	4	— 2	5	4	6
Russia	1	5	3	4	3	+ 2	3	2	3
Switzerland	11	12	5	6	2	— 9	2	1	5
Belgium	...	2	1	2	1	+ 1	1	1	2
Spain	5	7	1	...	...	— 5	...	...	...
Increasing	18	18	32	41	54	+36	56	56	49
Stationary	19	19	22	26	23	+ 4	24	24	28
Decreasing	64	62	45	33	25	—39	19	19	21

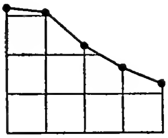
The most remarkable change, shown in Table II., is that of Germany, which passed from the fourth place in 1789 to the first place in 1869, and nearly quadrupled its percentage of membership during that time. The diminution of membership in France is almost equally striking, while the change in Great Britain is slight. The four countries grouped in the last line but two and the corresponding differences are: Germany, + 19; United States, + 7; Austria, + 6; Scandinavia, + 4. The increase in Austria is largely due to recent membership in the Prussian Academy, as shown in Table I., and is perhaps affected by proximity and a common language. The second group in which the change is small consists of Great Britain, + 3; Russia, + 2; Belgium, + 1; Holland, — 2. The third group, in which the percentage diminishes, contains: Italy, — 5; Spain, — 5; Switzerland, — 9; France, — 20. Evidently this grouping is not accidental, but is due to a common cause. The first and second groups include, in general, central and northern Europe, the Germanic, English and Slavonic races, and the Protestant countries. The third group includes in a marked manner southwestern Europe, the Romanic races and the Roman Catholic countries. The results for the German, English and French groups of countries, represented by the last three lines of the second to the fifth columns of Table II., are shown in the accompanying figure. Horizontal distances represent times and vertical distances, percentages of membership. In the first group the percentage of membership has increased about three times, in the last group it has diminished nearly two thirds. The numbers in the eighth and ninth columns, headed M and S, closely correspond to those in the sixth column, headed 1908.



German Group.



English Group.



French Group.

The grouping according to country may be studied in four ways. First, place of birth, to determine the effect of heredity or nationality. Second, education, as indicating the relative efficiency of different colleges or universities. Third, residence, indicating perhaps the best opportunities for work. Fourth, occupation, showing which universities have attracted the greater number of men of eminence. The third form of grouping only was considered in the former paper and is given there in Table III. Three of the European members, represented in Table II., have called my attention to the importance of the first form of grouping. It is not always easy to determine the place of birth, and in a few cases the nationality has been assumed to be the same as that indicated by residence. The most striking case of change is that of the United States. Of the six residents, members of 7, 6, 5, 4, 3 and 3 of the seven national societies, the three members of 7, 6 and 4 societies were born in other countries. The argument in the former paper, that better opportunities for advanced work should be furnished in this country, is thus greatly strengthened. Three of the residents in England were born in Scotland, or as many as in the entire United States. Holland is increased from three to five. The order accordingly becomes: Prussia, 18 members; England and France, 11 each; Holland, 5; Sweden and Switzerland, 4 each; Austria, Denmark, Italy, Norway, Russia, Saxony, Scotland and United States, 3 each.

The fourth method of grouping is easily made. Fifty-five of the eighty-seven members are given in Minerva as officers of one of twenty-six universities. Of these, Berlin has 9 members; Paris, 8; Bonn, Göttingen and Leipzig, 3 each; Cambridge, Christiania, Copenhagen, Erlangen, Harvard, London, Munich and Vienna, 2 each; Amsterdam, Berne, Bologna, Chicago, Heidelberg, Jena, Johns Hopkins, Leiden, Liège, Rome, St. Petersburg, Stockholm and Zurich, 1 each.

THE SCHOOL AND THE FAMILY

By J. McKEEN CATTELL

IN our complicated civilization a change in any direction may have unforeseen effects in other directions. If we do away with an aristocracy of birth, we leave room for a plutocracy and for politics as a trade; if we learn to use machinery, we throw into quasi-slavery a large part of the people; if we improve the means of communication and transportation, we build the tenement districts of the cities; if we develop a system of credits and exchange, we get public debts, panics, lockouts and congested wealth; if we use reason more, the surer instincts atrophy.

One of the cases where notable progress has yielded sinister by-products is the tendency of the school to weaken the family. Civilization may persist and progress without the family; but human and pre-human societies have been so completely based on it that no one can foresee the results of its destruction. Mankind will last only so long as children are born and cared for; and no plausible substitute for the family has been proposed. It is in any case evident that the premature weakening of the family will bring disaster; our reasoned efforts should at present be directed to its support and toward adjusting to it our newer adventures.

The school by its nature weakens the family, for it takes the children away from home and gives them interests not centered in the home. Within certain limits it may be a gain to polish homely wits and supply a new and wider outlook. The family can withstand a certain amount of aggression and may even be the better for it. But the notion is wide-spread that the more years a child spends in school, the more days in the year and the more hours in the day, the better it is, and that the scholastic trivialities inherited from the idle classes are the proper material for education. There is even approval of places like kindergartens and girls boarding schools, which are harmful both to the family and to the individual.

The sacrifice of the family to the school under the best of conditions is serious enough; it is distressing to see methods used that are wantonly destructive. If children are really more cultivated than their parents there is inevitable discord. We can only say that the older generation must suffer for the newer, the present family for the better family that is to be. But the emphasis on superficial book knowledge that is so common leads the young people to assume a superiority which they may in no wise possess in the more sterling qualities. We greatly overestimate the value of the three r's, the two g's and the one s. People are what they feel and do, much more than what they know; in any case the residuum of knowledge surviving the eight years of the elementary school is pitifully small.

One must learn to read in self defense. If ninety per cent. of the population carry pistols, it will not do for the remaining tenth to go unarmed. And people should learn to read in order to preserve and pass forward the social heritage, which may some time be the endowment of all, and is now the necessary condition for selection of those competent to improve or enjoy this heritage. But the present advantages of reading to the average individual are small, while it is probably injurious to family life. The main benefit of reading for most people seems to be that it is a substitute for alcohol, in which excess does not lead to such harmful consequences. The effect of reading the newspaper or current novel is similar to that from a small dose of alcohol or opium; it relieves conscious strain and the burden of routine individuality. A weekly journal or an ounce of alcohol on Saturday evening would doubtless be better than illiteracy or abstinence; but people will not run themselves as machines subject to the laws of utilitarian hygiene. The Bible may be read aloud and give solidarity to the family and community; the city newspaper absorbs the individual in transient details, not fit to be talked about or remembered. Its tawdriness distracts from homely interests. As a social factor, it is more likely to lead to national hysteria than to solid homogeneity.

There is relatively less to be said against writing and more in its favor. Its acquisition, while likely to be harmful to the immature nervous system, is less destructive than learning to read. What the average man reads is rarely worth while; what he writes is ordinarily of use. As a matter of fact, he writes very little, and could get on fairly well without that little. But of course, under existing conditions, every one should know how to write. I have found that practising on the typewriter for twenty minutes a day for two months, namely, a total expenditure of twenty hours, will enable people to write faster, not to mention legibility, than they could after eight years of schooling and twenty years of practising with the hand, though doubtless it is this practise that makes typewriting easy to learn.

It has become necessary for every one to deal with numbers and quantities, but it is a question as to how far the average man is helped in this by the school work in arithmetic, with the possible extension to geometry and algebra. One of the most persistent errors of our scholastic methods is the teaching of a child of a certain age with great labor and at the production of much stupidity what could be learned easily and with pleasure a couple of years later. It is possible to teach an infant to walk two months before the body is ready, but bow legs are likely to be the only permanent result. So it may be that the premature use of numbers apart from any real interest is actually harmful. The school work in arithmetic is certainly of very little use.

Exploitation of the conventional spelling and grammar is one of the insignia of the classes, which, like their dress and etiquette, is imitated by the masses without profit. The accuracy of spelling secured by school drill is useless; the syntactical limitations injure expression and style. Nothing much can be said in favor of geography, history and literature as they are taught, or for such science as now and then appears. We have a book method, essential for certain purposes, extended far outside the limits of its usefulness. The clerk or priest becoming teacher regards the elements of those subjects in which he is expert as the only ones proper to education, and the great mass of the people are ready to imitate those who have assumed authority over them. The futile system is supported *ex post facto* by a bad psychology, which claims that the methods used will teach children to observe, remember and reason. Primary education is planned as a preparation for the high school, and the high-school course as a preparation for college; the college is for students preparing for the professions and at the same time a club for the idling classes.

It is not at all clear why the public should pay a thousand dollars for the expenses of each boy who goes through college to enjoy the pleasures of drinking clubs and betting on athletics; and it is surely absurd to let the conventional courses of the college distort every elementary school. As Franklin said, there is a good deal of difference between a good physician and a poor physician, but not much difference between a good physician and no physician; and the same is true of the lawyer, the clergyman, the journalist and even the university president. We could get on tolerably well without all these gentlemen, except only the few who are working to advance knowledge and its applications; and it is, in any case, needless to make their production the principal aim of our educational system. The good ones are born fit for their work, and will do equally well whether they learn to read at twelve or at six.

The imprisoned hope of Pandora is the only justification of our educational system. We look forward to getting some day professional men who will serve a better civilization, and schools that will make children happier, wiser and more useful. In the meanwhile we consume on the altars of our schools more property than the lawyers can guard, more health than the physicians can restore and more unborn souls than the clergymen can save.

The unborn children due to the schools have been too little regarded.

From the very beginning of organic evolution the principal function of every generation has been the production of the next. The origin of each higher species has been an incident of this function, and man who looks before and after has been the final result. The ultimate outcome of evolution has been a rationalism that threatens to end the long process.

Last year the deaths in France exceeded the births by 19,920. In some departments there were less than seventy births to fill the places vacant by one hundred deaths. A patriotic Frenchman has written naïvely that this state of things is not so bad as it seems at first sight, as all civilized nations will soon be in the same condition. It is indeed true that the birth rate is decreasing in every country. The seriousness of the situation is obscured by the fact that the death rate is also decreasing, so that an increase of population has been as a rule maintained. But the decrease in the death rate can not continue indefinitely, and if present tendencies persist the birth rate will fall below the death rate everywhere, as has already happened in France and in New England.

It is now considered praiseworthy to postpone marriage until a family can be supported in comfort, and proper not to have more children than suits the pleasure of the parents. In 81 divorce cases tried in a month in a New York City court—divorces have trebled since 1870—the 162 married persons had among them 52 children. A census of twenty-two apartment houses in New York City proved them to contain 485 families and just 54 children—one child to nine families. These are the extreme cases; but among the educated and well-to-do classes the number of children does not nearly suffice to continue the race. The Harvard graduate has on the average seven tenths of a son, the Vassar graduate one half of a daughter.

These conditions are regarded as bad because the successful stocks are superseded; but to the present writer this does not appear to be the danger. There is probably not so much difference between one stock and another but that in each generation the place of the extinct families can be supplied from the inferior classes to advantage. A hereditary aristocracy is not maintained by inbreeding but by selection from below.

The fundamental danger to society lies in the fact that the pattern set by the ruling classes dominates; and this is especially true in a partial democracy, such as the United States or France. Where classes are distinct and permanent, each can have its own ideals, as it has its own dress. But when the hats and shoes of the rich are imitated by the middle classes, and those of the middle classes by the laboring classes, we may be sure that there will be a similar following of the leader in social customs and morals. If the two-child family is temporarily standardized for the upper classes, it will soon become the model elsewhere, and when one child takes the place of two, as it is already doing, the contagion will not be limited to the class in which it originates.

It may be that the population of the western world increased during the nineteenth century as rapidly as it could be assimilated. If Malthus had been correct in his theories it might be as anti-social and be made as illegal to have six children as to have two wives. But Malthus was a false prophet; thanks to the applications of science the means of subsistence have increased more rapidly than the population. If the density of population in the United States were equal to that in Great Britain, all the people in the world could live here; and they could live in comfort. There is a complete lack of the constructive imagination which might lead to bitter mourning for the hundreds of millions of human beings that might have been but are not, and to boundless regret for the science and art they might have produced for the benefit of all; but the decline and extinction of the race can not well be dismissed as a matter of no consequence.

It is now only to a limited extent the case that there are vigorous races waiting to take the place of those decayed. The Teutons may supplant the Celts, and be supplanted by the Slavs. If the negroes maintain their fertility and decrease their morbidity, and the eastern nations maintain their family sanctions, they may supplant the white races. But an extension of rationalism and a tolerably uniform world civilization will tend toward similar conditions everywhere in regard to the family and the birth rate. The past history of the human race is probably longer than its future history will be. Physicists tell us that the earth may be uninhabitable in twenty million years; it may be uninhabited by man in twenty centuries.

The disintegration of the family and the decline of the birth rate are due to many causes of which we need here concern ourselves with but two—the city and the school—for the object of this article is to offer a constructive suggestion intended to make these factors less destructive.

The modern city is surely subversive of the home and the family. Houses without individuality, dark and ugly, tenements and apartments, boarding houses and hotels, not owned by those who live in them, inhibit the instinct to form a home. Children do not stay in the house and can be put to no use about it. They are away at school and on the street; later they earn money for themselves. Women are not physiologically fit to bear and nurse children. The father is away all day, and the mother is often away. The parents and the children do not have work, amusements or interests in common. There are no family traditions and sanctions. A certain irresponsibility in the tenement districts gives a fairly large birth rate and a high infant death rate, but every advance in temperance and thrift decreases the birth rate.

It has been said that we must look to the country for men and to the city for ideas. But the trouble is that the city takes from the country its men and supplies it with ideas and ideals which are unfit. If paternalistic legislation and philanthropic efforts are of any use, they should be directed to the support of the family farm and the country home. A measure such as the protective tariff which builds up the manufacturing center and the city at the cost of the country should be regarded as intolerable. Measures such as agricultural experiment stations, the rural postal delivery and postal express should be welcomed. We need most of all to make life in the country attractive and fine, to lessen routine and incessant labor, to make each church and school a center for the social, intellectual and artistic life of a community.

The country school is at present no such place. Its general tendency is not to prepare children for usefulness and happiness in country life, but rather to make them inefficient and uncomfortable there and to send those who are more clever and ambitious away to the city. And the school shares with the city the bad preeminence of being one of the principal causes now working to break up the family.

It has been noted above that in so far as the school gives children interests not centered in the home, the family is inevitably weakened. This may be necessary in the interests of wider socialization, but in its methods and results the school contrasts unfavorably with the church, especially with the unreformed churches and the Hebrew synagogue. The sacraments of the church—baptism, confirmation, marriage, burial—are closely interwoven with family life; its services, ceremonies, fasts and fêtes are shared together by parents and children. In spite of inconsistencies in creed and in practise, the religious institutions both of the west and east tend by their observances and by their non-rational sanctions strongly to support the family. The school supersedes the church as a socializing factor to the injury of the family. In so far as this result is due to the methods by which the schools are conducted and the kind of instruction given, every effort should be used to find remedies or palliatives. In so far as it is due to the partial rationalization that follows, we are face to face with a difficult problem.

It may be thought that people are not likely to become too reasonable; nevertheless perhaps the principal danger to our civilization is the checking of instincts by rationalistic considerations. The instincts for mating, for forming a home and for the care of the young are prehuman and very strong. But like other instincts, they are only compelling for a limited period and under suitable stimuli. Postponement from prudential motives and the general conditions of modern life lead readily to their atrophy. This occurs first in the dominating and super-educated classes, and the model they set is followed in widening circles. Further it is noteworthy that there is no primitive instinct to have children; the instincts of mating, home-building and the care of the young suffice in the earlier stages; later the chief sanctions have been religious and tribal, and these are waning, largely through the influence of our educational methods. The reinforcement of instincts and impulses by rationally devised sanctions appears to be the only hope there is for the family and so far as can be seen now for the race.

Next after the rationalistic attitude implanted by our present methods of education and the diversion of the interests of children and young people from home life, the most serious injury to the family from the school is probably economic in character. It is said that a boy is legally of age at twenty-one, because for the first seven years of his life he is a charge to his parents, for the second seven years he is self-supporting and during the third seven years he repays the outlay for the first period. However this may be, there is no doubt but that children are more welcome when they add to the family income than when they take from it. A definite relation exists between the economic demand and the supply of children. A leading economist has argued that the population of the United States would be the same had there been no immigration. There are more children in farming communities and in factory towns than elsewhere; laws against child labor decrease the number of children.

As sentimental vegetarianism, if general, would exterminate most of the domestic animals, so humanitarian efforts for the welfare of children tend to exterminate them. The school is the most potent factor. When the well-to-do and professional classes must support their boys until the age of twenty-five and their daughters until twenty-two—a thousand dollars a year for each is not regarded as an excessive allowance—the limit of economic possibility is soon reached. And the burden on the poor is relatively as great when they send their children to school to the age of twelve or sixteen, after which they go off to shift for themselves. It looks as though the state would need to add to free schools not only free books, free sports, free transportation, free food and free clothes, but payment to parents for the time of their children—an ominous outlook for society. Charitable and state institutions other than schools, such as hospitals and old-age pensions, make children less desired. It is an old saying that a father can support seven children, but seven children can not support one father; still every father does believe that his children will come to his aid when needed. If he sends them off to school to be taken care of by the state, and in turn looks to the state to take care of him, the state may have to pay for the bearing of children as well as for raising them. And when states no longer want citizens for defense or aggression and have no peculiar institutions to support, it is not likely that the cosmopolitan world will be more ready than the individual to sacrifice present pleasures in order that there may be posterity.

In addition to the psychological and economic effects of the school subversive of the family, the physiological effects are serious. The health of our children is in large measure conserved by the inefficiency of our teachers. If children really did what our scheme of education asks, the results would be much worse than they are. It is also true that conditions at home, especially in cities, are such that the school may be an improvement. But the ordinary defective eyesight and lateral curvature of the spine are signs of deep-seated injury to the nervous system and bodily organs. Schools are centers for the spread of contagious diseases. The sedentary habits are not only injurious at the time, but are likely to persist, and the result is that but few educated people have normal circulations, digestions and reproductive systems. Alcoholic drinks, tobacco, coffee and medical drugs are used to replace the stimulation that should be obtained through normal work and out-of-door exercise. Some must do too much physical work and are never rested, while others shirk it altogether and are permanently tired.

It is generally assumed that the small family and diminishing birth rate are due to psychological and economic causes, but it is probable that physiological and pathological conditions are equally potent. When there is no child or but one, until recently at least, physiological infertility may be assumed; and this class represents one third of all families of college alumni. Among these alumni, a considerable percentage of whom are clergymen, large families such as were formerly common simply do not occur, and it is difficult to believe that voluntary restriction is absolutely universal. Among women of the American upper classes there are probably about as many miscarriages as births, and probably less than one fourth of all mothers can nurse adequately their infants. The small family is often due to voluntary restriction in deference to the health of the wife.

It is quite impossible to determine the extent to which the failing birth rate is due to physiological infertility or the extent to which this is chargeable to the schools. It has been held that intellectual development inhibits the reproductive function; in Malthusian days this was even urged as a beneficent plan of nature. Girls are injured more than boys by school life; they take it more seriously, and at certain times and at a certain age are far more subject to harm. It is probably not an exaggeration to say that to the average cost of each girl's education through the high school must be added one unborn child.

Our system of coeducation is favorable to conventional morality, but not to romantic love. A man is no more a hero to his girl chums than to his valet; a certain distance is necessary before the halo about a girl's head becomes visible. Small doses confer immunity to the larger passions. The 40,000 girls now in our colleges are putting off marriage beyond the age when impulse is dominant. This is regarded as one of the merits of the system; but it means that half of them will not marry and that the other half will have families of the average size of two children. Women of this sort ask too much of the men. They want a kind of education and a kind of interests that can not be universal; they are not content to begin with the simple servantless ménage that satisfied their parents. It is well for family happiness when husband and wife have interests in common; a university professor can have to advantage a college-bred wife. But the superficial culture of the American woman, the reading of the monthly magazines and best-selling novels, the frequenting of those theaters, art exhibitions and women's clubs, for which the husband has no time or taste, are not conducive to harmony and homogeneity in family life.

The economic employment of women in sedentary work and work away from home, which is such a marked development of modern and especially of American conditions, obviously tends to prevent marriage, to limit the number of children and to break up the family. When spinsters can support themselves with more physical comforts and larger leisure than they would have as wives; when married women may prefer the money they can earn and the excitement they can find in outside employment to the bearing and rearing of children; when they can conveniently leave their husbands should it so suit their fancy —the conditions are clearly unfavorable to marriage and the family. It is further an important consideration that men who must compete in the market with women can not afford to marry and support a family. Here again the school and the employment of female teachers are dominant factors.

There are in the United States about 400,000 women employed as teachers, and the numbers are continually increasing. In our cities there were at the time of the last census 76,348 female and 6,302 male teachers, and the proportion of females has since increased, so that now probably not more than one teacher in fifteen is a man. In one Ohio town there are about 200 female teachers without a single man. In the graduating class of a California normal school this year there were 272 girls and one man. In Germany, on the other hand, about two thirds of the teachers are men.

This vast horde of female teachers in the United States tends to subvert both the school and the family. The lack of initiative and vitality in our entire school system is appalling. The influence of our half million teachers on the problems of democracy and civilization is entirely insignificant. The attractive and normal girls and the few able men tend to drop out, leaving the school principal, narrow and arbitrary, and the spinster, devitalized and unsexed, as the dominant elements. Boys get but little good from their schooling and leave it when they can. Girls, who need men teachers even more than boys, predominate in the upper classes. Women are good teachers, especially young girls with their intuitive sympathy for children and mothers who have bred children of their own, and women are cheaper than men cf equal education and ability. But the ultimate result of letting the celibate female be the usual teacher has been such as to make it a question whether it would not be an advantage to the country if the whole school plant could be scrapped.

It has been urged that the backwardness of the middle ages was due to the fact that the ablest men were selected for celibacy; with equal plausibility it might be argued that the 400,000 American women teachers withhold the million children who might give to our country the intellectual distinction that it lacks. However this may be, it is certain that the homes and the children are lacking; and in every school patterns are set to be copied in the next generation with disastrous results.

It will doubtless be thought by most of those who read this paper that the futility of our present educational scheme and the evil effects of the school on the family have been exaggerated. The rhetorical phrases that have been used to give emphasis may leave an impression of lack of sanity and humor. It is indeed true that the shadows rather than the lights have been depicted. It would be possible to write in praise of universal education and the humanity of modern civilization, to tell once more how the American school opens the gateway to any career to every child, and how woman has been freed from a slavery as complete as that to which any race has been subjected. But it is not the object of this paper to relate the progress of civilization; its aim is to draw attention to certain poisonous by-products in the hope that antidotes may be found, and to make a suggestion tending in this direction.

The proposal—not likely to be heeded, for if it were, then its need would largely disappear—is that the teacher should be the family and so far as may be that the scholar should be the family.

In the last of the often-read tales that give distinction to American literature, we learn how the traveler, after a weary world search for the three fatalities that should give him love, treasure and influence, returns to his native New England village to find them there in a wife who had been the playmate of his childhood, in tilling the earth of his garden and in teaching the country children. One of the great novels of the greatest living master of letters tells how the heroine failed to find her hero in the warlord, but found him in the schoolmaster, when together among the hills they taught their boys the ways of truth and honor.

Is there indeed in all the wide world a better place than a home in the country where parents and children are doing what they can for themselves and for the neighborhood? The clergyman and the physician are, by the character of their professions, half missionary and half charlatan; in the lawyer and the journalist the missionary element is decidedly less. But there might be in this broad land of ours five hundred thousand men, as many women, twice as many children, all leading lives wholly useful and noble, as teachers in their communities. The money is there; the men and women are not lacking; the children need not be; it is only the spirit and the will that fail.

Can one not fancy a school in the country, the house a model of simple beauty, built and adorned from year to year by those whose use it serves? It would be adjacent to or perhaps a part of the home of the teachers, surrounded by gardens, orchards and barns. The house would be fitted out as a club, with books, pictures and music continually renewed. Its furniture, its lighting, its ventilation, its heating, its water-supply and baths, its workshop, its kitchen and laboratory, all would offer a standard for the neighborhood. In this house the children would gather, and so far as might be the older folks, for some two hours a day. The master and the mistress and their older children, with the help of others who were able, would teach the tricks of reading, writing and reckoning to those who lacked them, and all would be encouraged to go as far as they cared along the paths of letters and science. Two further hours might be spent in working about the place, in the shop, in the garden or with the animals, sewing, cooking or cleaning, learning to do efficiently and economically the things that must be done. The children and older folks would gladly return to the school for sports and games, indoors and out, for books and music, for theatricals, lectures and meetings, to eat and to gossip.

A school of this kind would be supported mainly by the work of those whom it served; perhaps no taxation would be required; in any case the money needed for the master, the mistress and their children to live in quiet elegance would not be much. The garden or intensively cultivated farm with the equipment of the school would need to be supplemented by a minimum of ready money. To each school might be added some productive concern—the raising of strawberries, mushrooms, or squabs, a creamery, smithy or printing shop. The teachers, and to a certain extent the people of the neighborhood, would be experts in some one line; they would do this special work as well as it could be done and be alert to improve the methods. Prentices would be trained who could carry expert skill to other neighborhoods.

The master and the mistress would have ample time. Four hours a day might be devoted to the children of the school, in work only partly sedentary. The wife could be spared when higher duties demanded, and the man could devote himself for a time to the completion of some pressing work. Both could have some trade or profession in addition to the teaching. It might be only the care of the school and garden—the postoffice would naturally be there—or the village shop might be added, or one of them might be skilled in carpentry, plumbing or surveying. They might edit and print the country newspaper, or a special journal whose edition of four hundred would go to all quarters of the world. One or both of them might be physicians, promoting hygiene and public health, knowing their own limitations and the limitations of the profession, able to refer patients to the best specialists within reach. Or one might be himself a specialist, spending part of the year at the university and city hospital, carrying forward researches in experimental medicine. The teacher might—could the jangling of the creeds be hushed—be the village clergyman; or he might be the lawyer, drawing up deeds and wills, suppressing lawsuits, showing the ways of justice and mercy. The teachers might be devoted to science, letters or art, perhaps applying the better methods to agriculture or industry, writing verses for the country papers, or training the choir; but here and there would be one able to move forward the boundaries of science, to write what would be read far off and long after, to create art in touch with the emotions of the people.

Five hundred thousand families, continually increasing in numbers, engaged in learning and in teaching, would give to this country a true democratic aristocracy. Into it would be taken the best elements of all the people, and from it would be chosen leaders in every department of human activity. Sons and daughters would return to carry forward the work of their parents; family sanctions and traditions would be maintained from generation to generation. Children would always be the chief concern in a home and in a school such as this. There would be no pathological, no economic, no psychological conditions at work for their extermination. Mothers fit to bear and nurse their young would be selected and trained. Children would not only be the chief treasure sought; they would also add to the material wealth of the family. Those who did not want children would be cast aside as little better than the abortionist and the infanticide. In all the world there is nothing more ultimate than the primitive voices of the two Rachels; Rachel weeping for her children, not to be comforted, because they are not; Rachel who said: Give me children, or else I die.

THE PROGRESS OF SCIENCE

WOLCOTT GIBBS

Oliver Wolcott Gibbs, one of the few great men of science given to the world by the United States during the first part of the nineteenth century, died at his home in Newport on December 9. He was born in New York City on February 21, 1822, his father, Colonel George Gibbs, being one of the earliest American mineralogists, and his mother, Laura Wolcott, the daughter of Oliver Wolcott, secretary of the treasury under Washington and Adams, being an artist of ability. Gibbs graduated from Columbia College in 1841, and received the degree of doctor of medicine from the College of Physicians and Surgeons in 1845. In the meanwhile he had been assistant to Dr. Robert Hare, professor of chemistry in the medical school of the University of Pennsylvania. The next three years were spent abroad; and work was carried on in the laboratories of Rammelsberg and Rose in Berlin, Liebig in Giessen and Regnault in Paris. In 1849 he became professor of chemistry and physics in the Free Academy, later the College of the City of New York, and in 1863 he was elected Rumford professor in Harvard University. In 1887 he became professor emeritus and retired to his home at Newport, where he equipped a laboratory for his chemical researches.

The researches that he accomplished give distinction to this country. His work on the electrolytic deposition of copper as a means of quantitative analysis has become of great significance, and many other methods of quantitative analysis were improved under his guidance. Other works of great importance were his extended experimental studies of complex salts, especially the cobaltamine compounds and those containing some of the rarer elements. These are of great theoretical interest, owing to their relation to theories of molecular structure.

Gibbs was the last surviving founder of the National Academy of Sciences, which he served as president; he had been general secretary, vice-president and president of the American Association for the Advancement of Science. He was a member of the Prussian Academy of Sciences and the only American honorary member of the German Chemical Society. His work was recognized by many other societies, and by honorary degrees conferred by Columbia, Harvard, Pennsylvania, George Washington and Toronto Universities.

A portrait of Gibbs was published in The Popular Science Monthly for June, 1900. There is here reproduced a letter addressed to the editor in answer to a request for an article. This letter illustrates the courtesy and kindness not less characteristic of Wolcott Gibbs than the eminence of his services to science.

OTIS T. MASON

Otis Tufton Mason, head curator of the department of anthropology in the United States National Museum, died at Washington on November 5, in his seventy-first year. He was the son of John and Rachel Thompson (Lincoln) Mason, and was born at Eastport, Maine, April 10, 1838. He was graduated from Columbian (now George Washington) University as A.B. in 1861 (A.M., 1862; Ph.D., 1879; LL.D., 1898). In the following year he married Sarah E. Henderson, and at once entered on his career as a teacher. As principal of the preparatory department of Columbian College, from 1861 to 1884, he used his oppor-

Oct 5th 1904

GIBBS AVENUE
NEWPORT R. I.

Dear Prof Cattell

I would very willingly comply with your request to write for your excellent and most valuable journal but I am wholly unable to do so. I am now in my 83d year and do little besides keeping up with the progress of Science as well as I can but without offering any suggestions or thoughts of my own. You are doing excellent work and I sincerely wish that I could aid you

Very cordially Yours

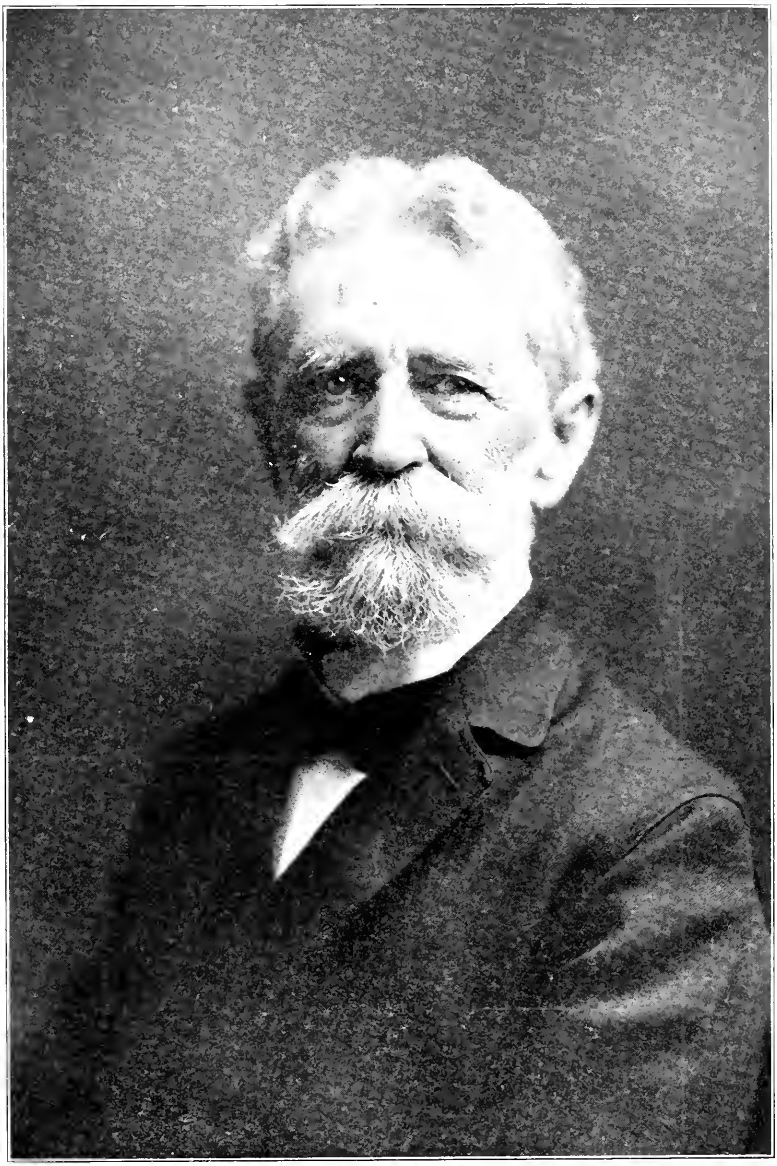
Wolcott Gibbs

tunities for leading the young into correct methods of study, and every leisure moment out of the classroom for perfecting himself in those original investigations that were his life work.

Mason's interest in anthropology began in his boyhood days, and his inspiration may be traced directly to the enthusiasm with which he read a copy of Guyot's "Earth and Man" that accidentally came into his hands. Following Guyot, the writings of Maury, Guizot, Lane Fox, Klemm, Lubbock, Tylor and Evans were devoured, and his text for life became "thoughts in things, or human history written in human inventions." Ever a devout churchman and a leader in Sunday-school work, he equipped himself with a knowledge of Biblical archeology, which subject he pursued assiduously whenever opportunity afforded. His deep and growing interest in this and kindred studies attracted, in 1873, the attention of Professor Joseph Henry, secretary of the Smithsonian Institution, through whose influence Mason's studies became diverted to the American field at a time when but few students were aware of the fruitfulness and the possibilities of the western continent for ethnological and archeological research. In the same year he was made a collaborator of the Smithsonian Institution, and commenced to compile the synonymy of the North American tribes—the inception of what has developed into the "Handbook of American Indians," now in process of publication by the Bureau of American Ethnology. He also prepared schemes for anthropological exhibits at the Centennial Exposition in 1876, and became the editor of the anthropological summaries that appeared in "Harper's Annual Record of Science and Industry" (1874–8), in the *American Naturalist* (1876–87), and in the *Smithsonian Reports* (1875–93). Professor Mason was appointed curator of anthropology in the United States National Museum in 1884, and head curator of its department of anthropology in 1902.

Otis Tufton Mason was the most charming of men. Kind, generous, considerate, patient beyond measure, with a fount of humor that bubbled forth on every occasion, one would never suspect from outward appearance that the best years of his life had been blighted by mental anguish. Paralyzed after having passed his sixtieth year, he began life anew, as years before he had begun again, after years of application, when Henry advised him to drop the eastern Mediterranean field and adopt America as the subject of his labors. His right hand being practically dead, in a few weeks he learned to write as well with the left, and planned further work with bravery worthy of a young man in prime physical condition.

Being essentially a worker among collections, Mason's activities were devoted chiefly to the material culture of primitive peoples. This is exemplified by his writings on the "Latimer Collection of Antiquities from Porto Rico" (1876); "Basket-work of the North American Indians" (1884); "Throwing-sticks in the National Museum" (1884); "Cradles of the American Aborigines" (1887); "North American Bows, Arrows and Quivers" (1893); "Origins of Inventions" (1895); "Aboriginal American Zootechny" (1889); "Aboriginal American Basketry" (1902), and many others. He insisted that the most rigid methods of the naturalist should be applied to the investigation of human problems, and that every human act and invention be subjected to this close scrutiny. His long experience in the training of youth made him ever a willing guide and instructor of those in search of the knowledge that he possessed, and many a young student received his first impetus in the study of ethnology through Mason's friendly aid. His scientific papers, numbering many score, are written largely in popular vein, as if designed for the benefit of youth rather than for his fellow



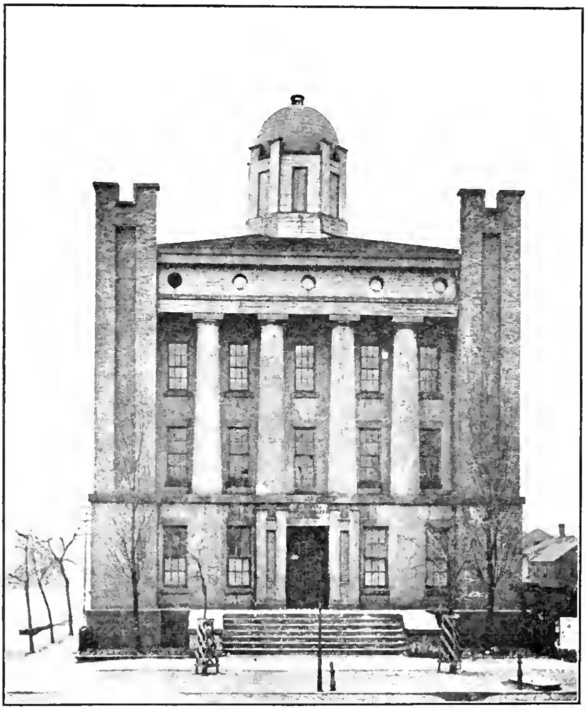
OTIS TUFTON MASON.

workers. With Mason passes one of the founders of the Anthropological Society of Washington in 1879, in the activities of which he took a most prominent part while health lasted, serving as its president from 1893 to 1895. His associates will miss his cordial greeting, his fatherly advice and encouragement, his tender sympathy, the cheering atmosphere that one always felt when in his presence. In time to come Mason will be recognized as the pioneer in the classification and analysis of the material culture of the American aborigines.

THE H. K. CUSHING LABORATORY OF EXPERIMENTAL MEDICINE OF WESTERN RESERVE UNIVERSITY

The school of medicine of the Western Reserve University, which is one of those in this country maintaining the highest standards, has been fortunate in receiving from Mr. H. M. Hanna and Colonel Oliver H. Payne a gift of $200,000—to which they have just added $17,000 towards the endowment—for a laboratory of experimental medicine, named in honor of one of the distinguished professors of the school in its early days. The laboratory was dedicated on November 20, when, after a welcome by President Thwing, the principal address was made by William H. Welch, M.D., LL.D., professor of pathology in the Johns Hopkins University. An address was also made by George Neil Stewart, D.Sc., M.D., professor of experimental medicine and director of the new laboratory.

The new laboratory adjoins the main building and the physiological laboratory building of the Medical School.

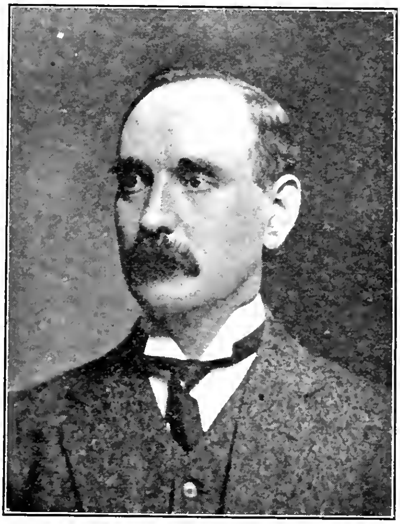


The original building of the Western Reserve Medical School, erected in 1844 for the Cleveland Medical College. Replaced in 1887 by the present main building of the Western Reserve University Medical School.

It is four stories high, of reinforced concrete, faced with brick, and complete in all its appointments. The building contains laboratory rooms, a balance room, a library, photographic rooms, rooms for individual investigations, a refrigerating room, rooms for conducting studies in the nutrition of animals, store rooms, workshops and the office of the director.

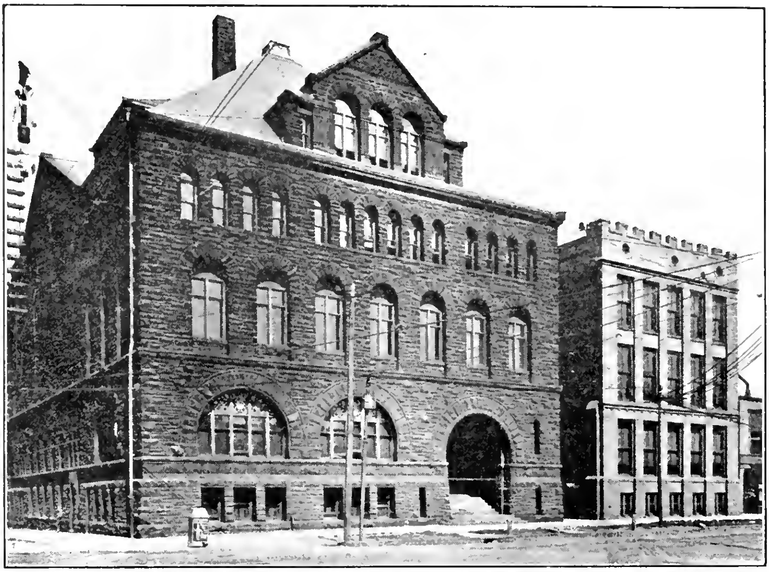
The H. K. Cushing Laboratory will fill an important place in the field of medical research and education. So long as medicine was a comparatively simple science it was possible for the physician, while actively practising his profession, to keep himself sufficiently in touch with the fundamental medical sciences such as physiology, anatomy and pathology. The rapid advance, both in the practical arts of medicine and surgery and in the underlying sciences on which they depend has rendered it impossible for any one man to dominate both fields. Therefore the time seems to have come for improving the means of coordinating practical medicine and the medical sciences. It is proposed to accomplish this at the Western Reserve University by the establishment of a laboratory and chair of experimental medicine, the occupant of which and his assistants shall be expected to keep themselves in touch, so far as is possible, with clinical work, on the one hand, and physiology and pathology, on the other, and to encourage and direct investigation having a bearing upon both. The new foundation is intended to form a link between the knowledge of the laboratory and the knowledge of the hospital.

DR. WILLIAM H. WELCH,
Professor of Pathology in the Johns Hopkins University, who delivered the principal address at the dedication of the H. K. Cushing Laboratory of Experimental Medicine of Western Reserve University.



DR. NEIL STEWART,
Professor of Experimental Medicine and Director of the H. K. Cushing Laboratory of Experimental Medicine of Western Reserve University.

The researches which in the future may be carried out in this laboratory are planned to have, as far as possible, a direct practical bearing upon clinical questions. For example, some light has been thrown by experimental investigation on the pathology of such conditions as goitre, diabetes, gout, the anemias, ulcer of the stomach, etc.,



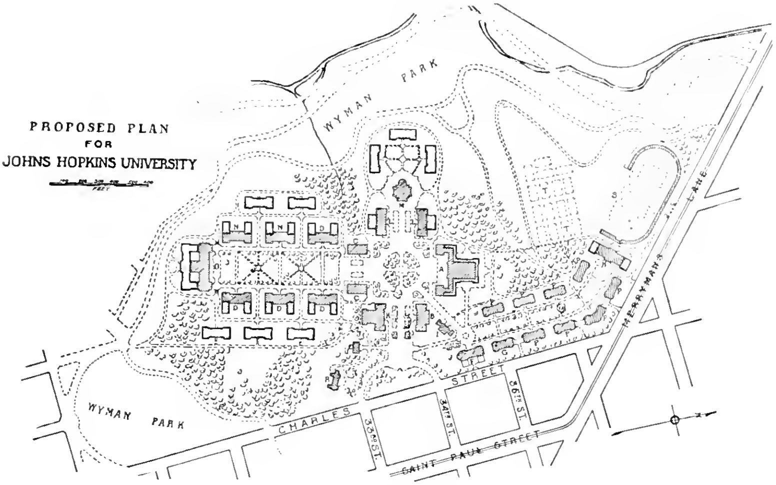
THE MAIN BUILDING AND PHYSIOLOGICAL LABORATORY BUILDING OF THE WESTERN RESERVE MEDICAL SCHOOL, Cleveland. The main building is of brown stone, and comprises four floors and a basement. It contains two amphitheaters and the Laboratories of Anatomy, Histology and Embryology, Pathology and Bacteriology and Pharmacology. The building was first occupied in 1887 and cost $240,000. The Physiological Laboratory was built in 1898. It houses the Laboratories of Physiology and Physiological Chemistry with private research rooms and work shops.

but very much remains to be discovered. A deeper insight into problems of this kind may be obtained if investigators at the same time as they are working at the subject from the experimental standpoint in the laboratory, are in a position to study clinical cases of the disease in the hospital, and this it is planned to do in the H. K. Cushing Laboratory.

THE CONVOCATION WEEK MEETINGS AT THE JOHNS HOPKINS UNIVERSITY

THE scientific meetings to be held at Baltimore during the week following that in which Christmas falls promise to be of very great interest. In addition to the American Association for the Advancement of Science, with its eleven sections covering the entire field of the natural and exact sciences, no less than twenty-five independent societies will meet in affiliation. These national societies include those devoted to mathematics, physics, chemistry, geology, geography, paleontology, physiology, astronomy, bacteriology, zoology, entomology, botany, psychology, philosophy and anthropology. The officers and members of the American Association, of the American Society of Naturalists and of these special societies, are practically identical with the productive scientific men of the country. It is likely that fully two thousand of them will be at Baltimore and that the number of papers read will exceed five hundred.

While the special scientific societies and their technical programs are probably the chief factors promoting and guiding the advancement of science in this country, a large meeting of scientific men has certain other advantages, the most important of which are per-



Present needs: A, Library; B, Administration Building; C, C, Class Rooms; D, D, D, D, Laboratories; E, Levering Hall (Y. M. C. A.); F, Dining Hall; G, Dormitory; H, Gymnasium; S, Athletic Field; T, Tennis Courts. Future needs: K, Assembly Hall; L, L, Museums; M, Chapel; N, N, Laboratories; O, Museum; P, P, P, P, P, P, P, Dormitories; R, President's House.

haps the widening of personal interests and acquaintance, and the development of a spirit of loyalty to science and scientific ideals. The machinery for conducting a large meeting of this character is not fully adjusted—it is only five years ago that the first of the convocation week meetings was held in Washington—but each year the friction has become less, and the advantages have become more evident.

The first general meeting will be held at ten o'clock on the morning of December 28 in McCoy Hall of the Johns Hopkins University. Addresses of welcome will be made by Dr. Ira Remsen, president of the university, and Dr. William H. Welch, chairman of the local committee, both past presidents of the association, and the president of the meeting, Professor T. C. Chamberlin, will reply. In the evening, the retiring president, Professor E. L. Nichols, will give his address, and during the week the vice-presidents for the sections and the presidents of many of the special societies will make addresses. These will in most cases be of general interest to scientific men, and special sessions will be arranged that will be of general interest. The most notable is an entire day (January 1) with a dinner in the evening devoted to the celebration of the one hundredth anniversary of the birth of Charles Darwin and of the fiftieth anniversary of the publication of the "Origin of Species." A symposium on public health will be held on December 31.

When the Johns Hopkins University was opened in 1876, it adopted the wise policy of spending its means on men rather than on buildings. Its laboratories are, however, admirably equipped, and with its medical school—unfortunately at some distance from the other departments—it offers all needed facilities for a large scientific meeting. The university will, when money is obtained, remove to the beautiful site it has purchased on the outskirts of the city. In addition to athletic grounds there is at present in use only some equipment for the botanical department. The site will be developed and buildings erected in accordance with the plan here given.

SCIENTIFIC ITEMS

In addition to Wolcott Gibbs and Otis T. Mason, the country has lost in the death of William Keith Brooks one of its most eminent men of science. A biographical sketch of Professor Brooks, who had been professor of zoology at the Johns Hopkins University since 1876, together with a portrait, will be found in the issue of The Popular Science Monthly for July, 1899. We regret also to record the death of Dr. Andrew J. McCosh, a leading surgeon of New York City; of M. Alfred Ditte, the French chemist, and of W. E. Ayrton, the British physicist and electrician.

Dr. Richard C. MacLaurin, for the past year professor of mathematical physics in Columbia University and previously professor of mathematics in the University of New Zealand, has been elected president of the Massachusetts Institute of Technology.—Professor W. W. Campbell, director of the Lick Observatory, has been appointed lecturer for next year on the Silliman foundation at Yale University.

Nobel prizes in the sciences for 1908 have been awarded as follows: For chemistry, Professor Ernest Rutherford, director of the physical laboratories of the University of Manchester, England; for physics, M. Gabriel Lippmann, professor of physics in the University of Paris; for medicine, divided between Dr. Paul Ehrlich, of Berlin, and Professor Elie Metchnikoff, of the Pasteur Institute of Paris.

The Royal Society has awarded medals as follows: the Copley medal to Dr. Alfred Russel Wallace, in recognition of the great value of his numerous contributions to natural history, and of the part he took in working out the theory of the origin of species by natural selection; the Rumford medal to Professor H. A. Lorentz, for his investigations in optical and electrical science; a Royal medal to Professor John Milne, for his preeminent services in the modern development of seismological science; a Royal medal to Dr. Henry Head, for his researches on the relations between the visceral and somatic nerves and on the functions of the afferent nerves; the Davy medal to Professor W. A. Tilden, for his discoveries in chemistry, especially on the terpenes and on atomic heats; the Darwin medal to Professor August Weismann, for his eminent services in support of the doctrine of evolution by means of natural selection; the Hughes medal to Professor Eugene Goldstein, for his discoveries on the nature of electric discharge in rarefied gases.

THE
POPULAR SCIENCE
MONTHLY.

FEBRUARY, 1909

THE NATIONAL EXPOSITION AT RIO DE JANEIRO

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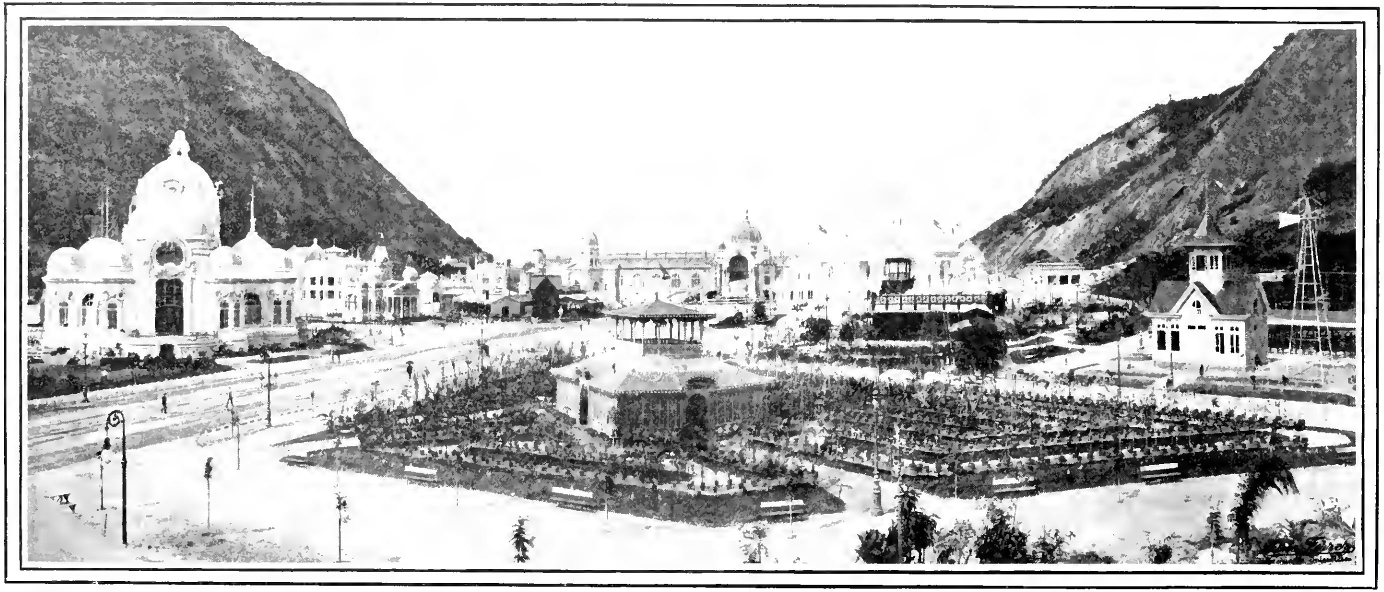
A MONTH later than the date originally set for its opening, the first National Exposition of Brazil was officially inaugurated on August 11. Patriotic pride in the gratifying evidence which the exhibits give of Brazilian arts and industries, and of Brazilian progress, is the dominant note everywhere. As one of the leading newspapers of Rio has enthusiastically said:

> The one feeling that every one has in his heart is an immense satisfaction, an overwhelming patriotic joy, as he sees this splendid exposition which gives evidence of our national capacity for work, and of our national vitality.

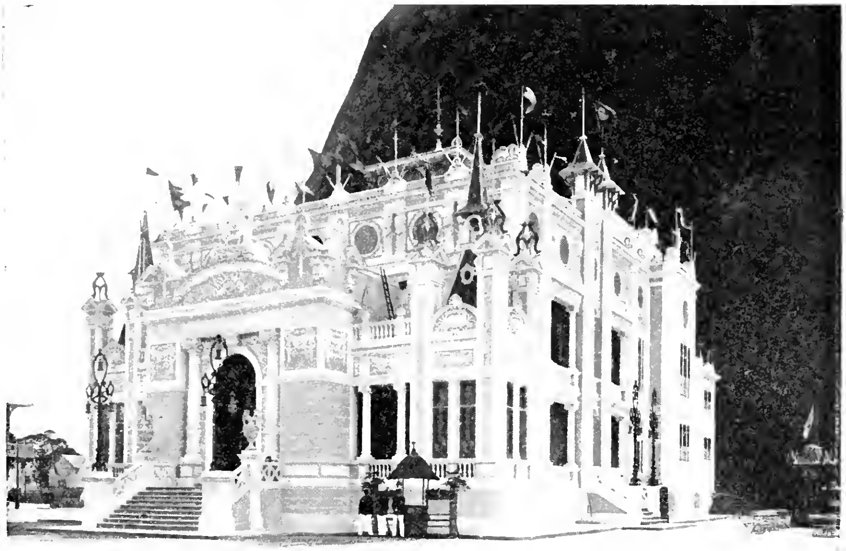
In his opening address, the president of the exposition commission referred to the important event in the history of Brazil which the exposition commemorates, viz., the opening of the Brazilian ports to the commerce of the world, one hundred years ago (January 28, 1808), and to the desire of the present government to bring together, on this centennial anniversary, the evidence of Brazilian progress in the last one hundred years. There have, it is true, been previous exhibitions, on a small scale, along similar lines. Thus, the Brazilian exhibits which were sent to London in 1862; to Vienna in 1873; to the Centennial in 1876; to Paris in 1889; to Chicago in 1893, and to St. Louis, were previously collected and open to the public in Rio. But the present exposition is far more representative and more complete than any of these others. Every one of the twenty states of Brazil is here represented, as well as the Federal District of Rio de Janeiro and the territory of Acre, "that precious piece of land recently added to our national demain," as one newspaper characteristically puts it, and goes on to say, "All the cells of our national organism here palpitate



Panorama of a Section of the National Exposition Grounds.
In the foreground is the Botanical Garden Pavilion. To the left is that of the San Paulo, and to the right the Federal District Pavilions. The Textile Industries Building is in the background. This illustration and the other illustrations used in this article are printed here by the courtesy of the Editor of the *Bulletin* of the International Bureau of American Republics.

with life, showing the latent force which is impelling us on to the magnificent destiny prepared for our country by a Divine Providence."

The background, with Rio's wonderful hills, and the foreground, with Rio's magnificent bay, combine here to make a natural setting which it is safe to say no national or international exposition has ever had. No artificial lakes and canals, picturesque as these may be; no magnificent buildings; no marvels of electric lighting; no fountains or cascades—none of the things that have made other expositions famous, can compare with what nature herself has done in giving Rio de Janeiro this splendid harbor and these mountains, here green and soft, there grim and bare, with the famous "Sugar Loaf" guarding the entrance to the harbor on one side of the exposition grounds, and the precipitous Corcovado, towering up like a sentinel above the city, on the other. To readers who do not know Rio de Janeiro, the words of the opening address, in which the beauties of the city were enthusiastically described, will seem like undue exaggeration. The speaker said:



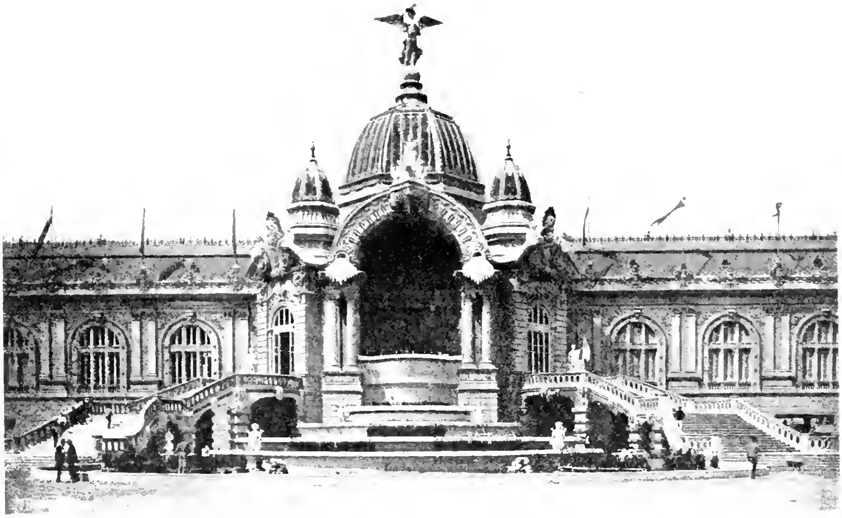
THE EXPOSITION THEATER.
The theater has a seating capacity of about 750.

> The most beautiful city in South America, where the deep sea and the laughing bays; the high and solemn peaks; the gently-sloping hills; the rows of houses bathed in sunshine or showing, less distinctly, in the lights of the rosary of diamonds which surrounds the shores, fantastically mirrored in the waters of the bay—these combine to give a picture which is wholly unique in

the world—to strangers, a surprise and an enchantment; to us Brazilians a source of pride.

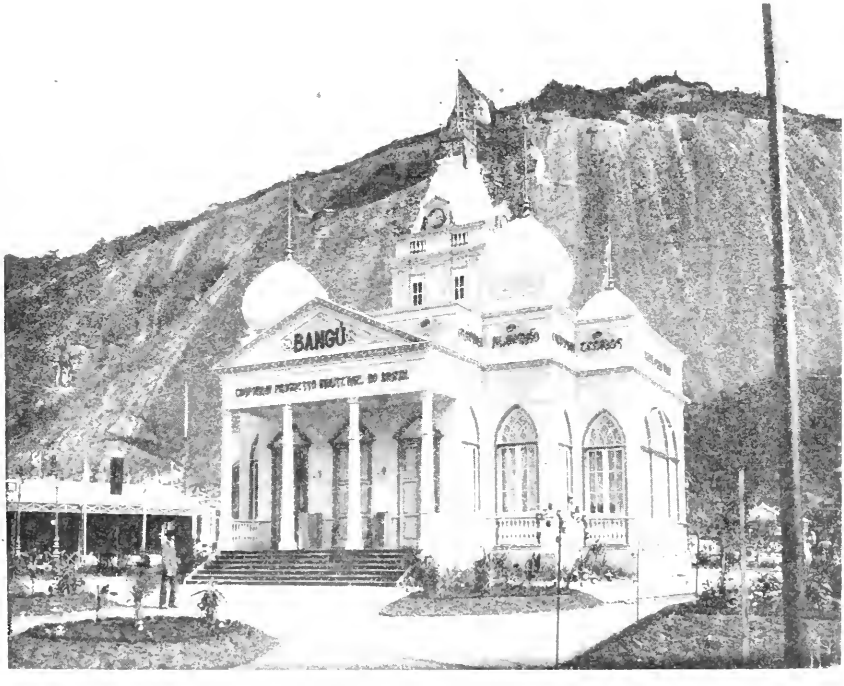
The visitor who comes to Rio with the idea that he is to see a grand exposition, on a large scale, will be disappointed. Compared with any of the international expositions, this Brazilian undertaking is naturally very small. It covers but little ground. Its buildings are few in number, and not notable for size, beauty of architecture, or originality of arrangement. The exhibits are not numerous, nor are they very impressive, to the casual visitor. But the Rio Exposition means very much to Brazilians. Seen with their eyes, it embodies the spirit of their national progress: it gives tangible evidence of what Brazil can do in the way of products and manufactures: it serves to show that Brazil is becoming less dependent upon foreign countries: it therefore strongly appeals to the patriotic side of the people. When looked at by a foreigner so far as possible with Brazilian eyes, this exposition is not merely interesting; it is well worth careful study. The location was wisely chosen, at the southern end of the city, near the old military school, where the land now occupied by the exposition buildings was largely wasted. That quarter of the city will, from this time on, assume a different aspect. Most of the money which has been spent by the government has gone into permanent buildings. The

THE PORTUGUESE PAVILION.
This pavilion was erected and offered by Brazil to the Portuguese nation for exhibition purposes.



THE TEXTILE INDUSTRIES BUILDING.

This monumental structure, surmounted by a statue of Fame, is the remodeled Military Academy.



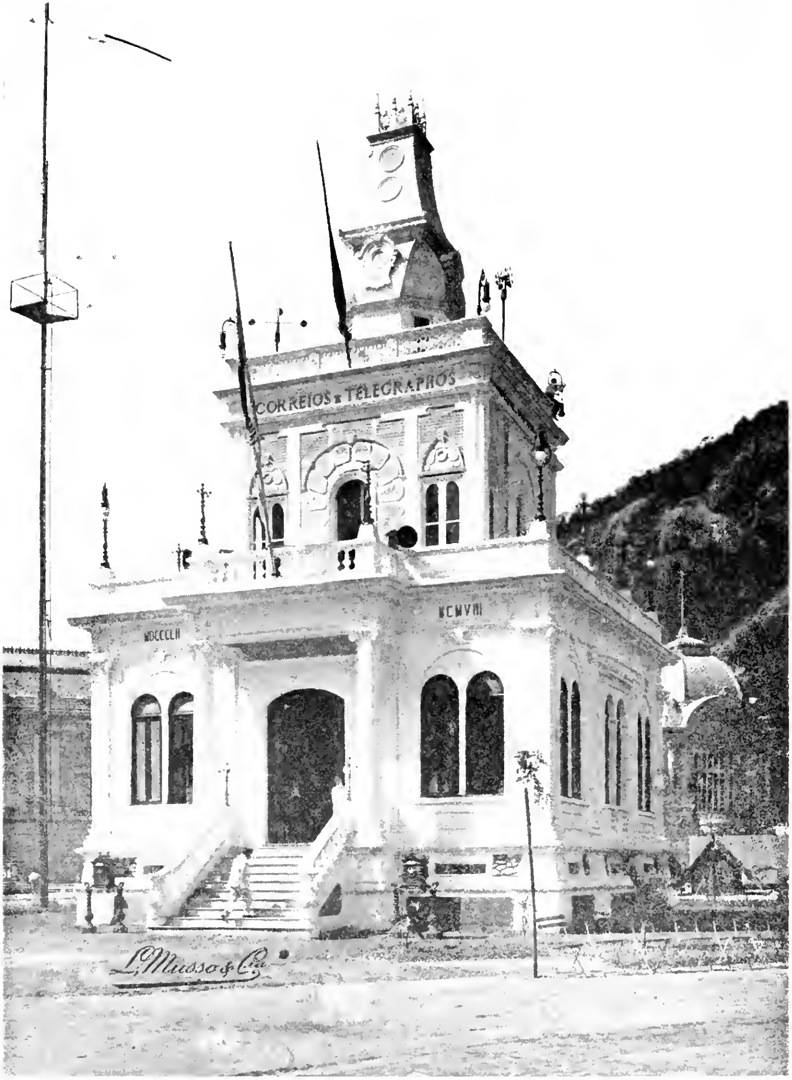
THE BANGÚ FACTORY BUILDING.

This building was erected by the Bangú Textile Mills for the exhibit of its products.

Exposition Palace.
The palace was used for official receptions during the exposition and for the exhibits of those states which had no special buildings. It was formerly the War University.

old military school building was largely torn down and then rebuilt, and one of the other buildings, which before was standing half-done and unused, has been completed and made into a fine permanent structure of stone. The land has been graded and cleared. A new sea-wall and boulevard have been built out to the exposition grounds. This is all clearly for the permanent advantage of the city, although the exposition itself, as a whole, will doubtless be a financial failure.

Brazil is an immense country. From the northern states with their vast forests—which most of us make the mistake of thinking cover the larger part of the country—to the southern states of Rio Grande do Sul and Santa Catharina, it includes climates of many kinds. The visitor to this exposition will see rubber and wheat; sugar-cane and corn; cotton, rice, manioc, coffee, maté, grapes, tobacco, alfalfa, sorghum. He will see most of the familiar vegetables and cereals of home, and next to them can examine the characteristic tropical woods from the forests of the Amazon. Amazonas and Para on the north have sent the products of the tropics; Minas Geraes has sent its famous cheeses, made from the milk of cows pastured on its great inland campos, as well as specimens of its gold and diamonds and precious minerals, and a fine model of its well-known Morro Velho mine. Santa Catharina on the south sends wheat and corn, wine, tobacco, cotton, coffee, dried beef, cheese, tinned butter, and the like—products of its temperate climate and of its cattle industry. It is probable that most Brazilians, as well as most foreigners, will be surprised at the variety of food-stuffs here exhibited, but it is certain that few visitors to this exposition will expect to see such evidence as is here given of the development of different industries in Brazil. Even the leading newspapers of Rio express surprise at the exhibits of cotton and woolen cloth; of footwear and of hats; of canned foods; of wines and beer; of dairy products, furniture, glassware, pottery and iron-work. The pride of Brazilians is especially appealed to by the exhibit of native foundry-work, of agricultural implements and of machinery of various kinds, for preparing rice, manioc, coffee and sugar-cane. By "special concession" on the part of the government, Germany and the United States have been permitted to exhibit machinery, some of it in operation. The former country shows agricultural implements and machinery for preparing rice, manioc, etc. From the United States there are exhibits by the United Shoe Machinery Co., the Continental Gin Co., of Birmingham, Ala., the Oliver Chilled Plow Co., of Indiana, and the Loomis Co., of Indiana. The Federal District (Rio de Janeiro) makes an effective showing with furniture and cabinet work, carriages and wagons, flour, glassware, laces, some excellent pottery and tiles, drugs and chemicals, bricks, wooden-ware, wire work, and a good collection of vegetables (fresh and dried) grown in the market



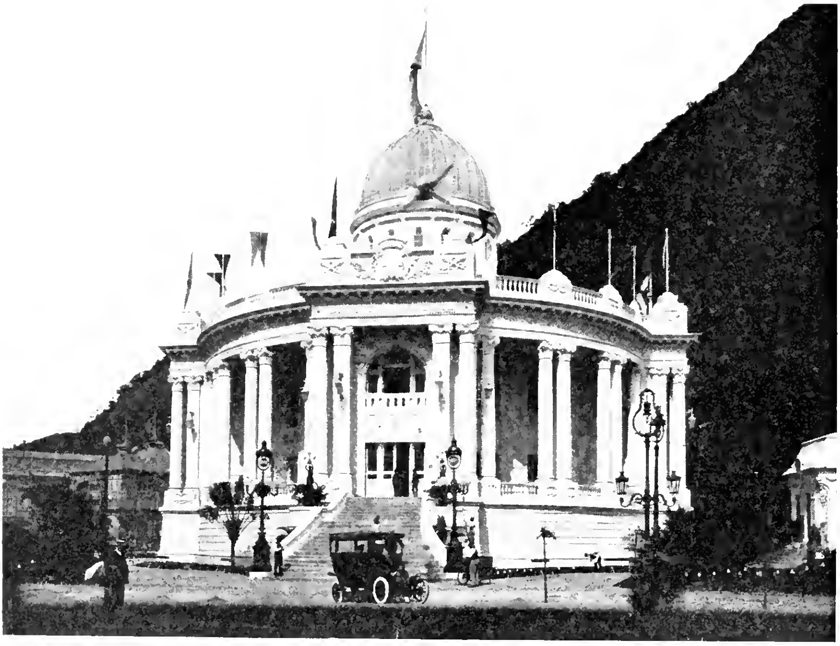
Post-office and Telegraph Building.

gardens around the capital. Para, at the mouth of the Amazon, sends pottery and tiles; and an excellent exhibit from one firm in the city of Porto Alegre (State of Rio Grande do Sul) includes metal bedsteads and other articles of furniture, stoves, galvanized iron-work, safes, locks, etc., which would look well in any exposition anywhere. Those who have traveled in Germany will see unmistakable evidence of German skill and workmanship in the Santa Catharina exhibit of

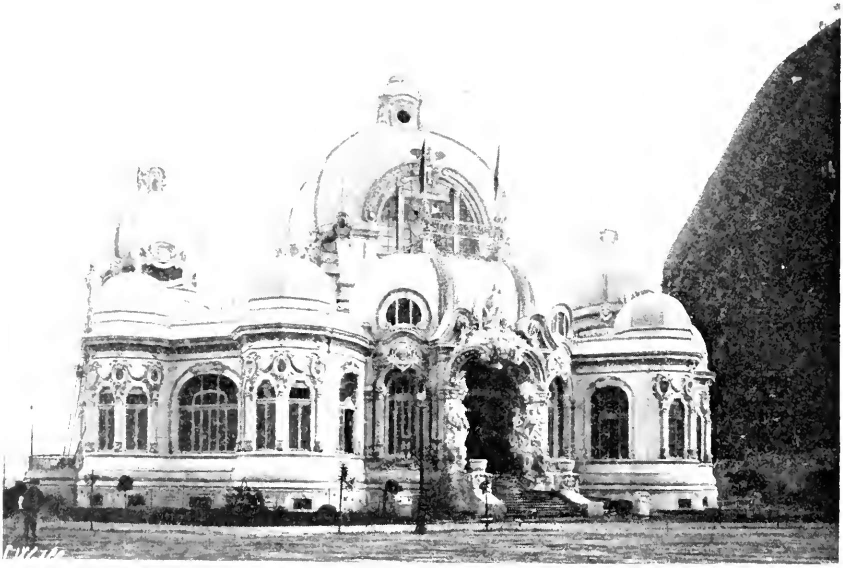
AGRICULTURAL DEPARTMENT BUILDING.

needlework and embroidery, baskets, furniture and woodenware, and oil paintings, and a copy of "Der Urwaldsbote," published in Blumenau, shows that the language of the Fatherland is not forgotten in the midst of the new surroundings of Brazil.

Mere enumeration of the kinds of exhibits is tedious alike to writer and to reader; it leaves a confused impression on the mind. In any exposition, even a small one such as this in Rio, the best that can be done is to single out a few things for special mention. The exhibit made by the director of the Botanical Garden is representative, so far as it was possible to make it under the circumstances. In and around a glass pavilion there are shown, in pots, 1,337 selected plants, all care-



FEDERAL DISTRICT BUILDING.



THE SAN PAULO PAVILION.

The San Paulo Building stands next to that of Minas Geraes, and covers an area of 4,593 square feet. It was one of the finest buildings of the exposition.

fully labeled and classified. These include 245 palms, 144 ferns, 112 fruits, and a large number of specimens of special economic and medicinal value, including dyewoods. The colors of the labels distinguish the different groups of plants. For example, dark green is for medicinal plants; white for cotton; red for the purely ornamental; yellow for fibrous; vermilion and white for dyewoods; vermilion for oil and resinous; etc. The opportunity here afforded, of a close examination, within a conveniently restricted area, of the characteristic plants of Brazil, is an excellent one. A collection of all the publications of the Botanical Garden is arranged inside the glass pavilion, and includes two volumes of the splendid work by Dr. Barbosa Rodrigues, the director of the garden, "Sertum Palmarum Brasiliensum." These volumes are placed on an inclined shelf, where they may be freely consulted by any visitor, and are not even fastened in any way to the shelf. The authorities must have abundant faith in the honesty of the public here. Or perhaps it may be the duty of some watchman—who was absent on the occasion of the writer's visit—to guard these books.

The Astronomical Observatory of Rio has put on exhibition a Wiechert seismograph, recently imported from Germany. This machine is of a somewhat simpler pattern than the Bosch-Omori seismograph, lately installed in the Geological Section of the Harvard University Museum, at Cambridge. It is very badly set up so far as detecting earthquake shocks is concerned, for it cannot fail to be affected by the movements of the people who are walking about on all sides of it, but the writer was given to understand that, for exhibition purposes, it was desired to have the public see, with its own eyes, how sensitive such a machine is, and from that point of view it is admirably exposed! The observatory exhibit also includes several large diagrams showing the variations in the different weather elements at Rio during the year. Here one may see the extraordinary preponderance of winds from southeast and from northwest; the slight changes in temperature throughout the year; the marked rainy season of summer; the higher pressure, clearer skies and drier air which characterize the winter. Another meteorological exhibit is that of the meteorological department of the Brazilian navy. This branch of the government has charge of the daily weather map and of the daily weather forecast, and has a small working meteorological station in the cupola of the building of the mail and telegraph service, where the work is explained and the forecasts are displayed.

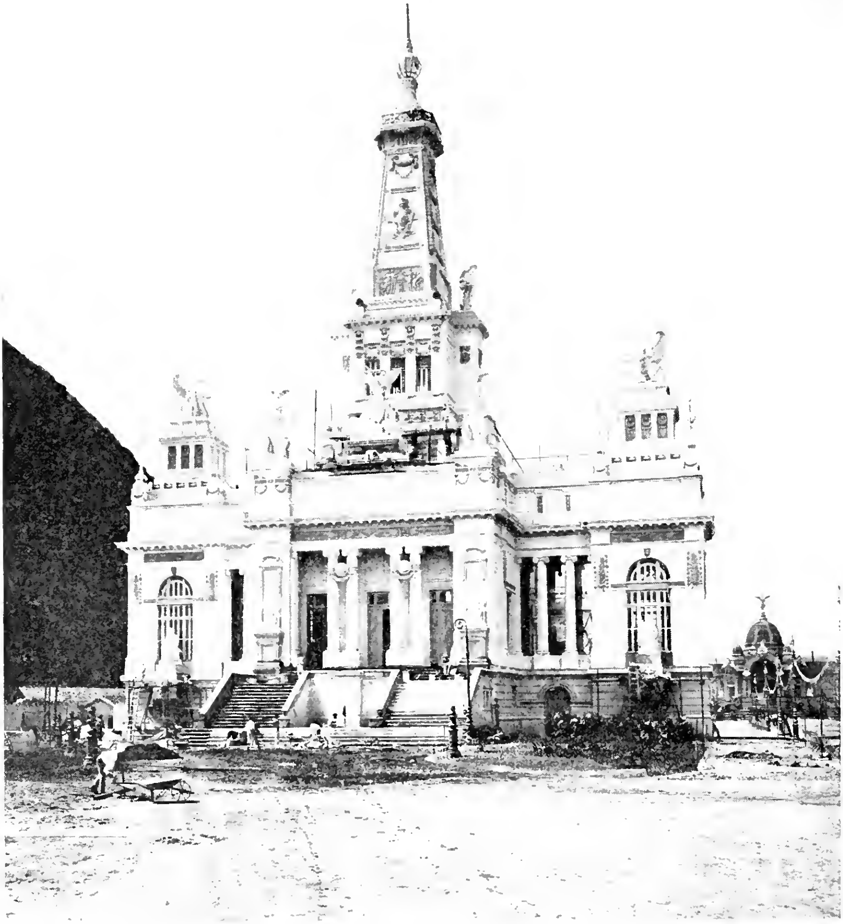
The broadest generalization that one can give regarding the exhibits as a whole is that the southern states of Brazil are far ahead, industrially, of the central and especially of the northern states. This results naturally from the fact that the southern states have a far more extended railroad development and are—or rather because they

Bahia Building.

The Bahia Pavilion occupies an area of 54,359 square feet. The exterior is adorned with two majestic statues of Justice and Science, and a central group consisting of figures bearing a shield, representing the State of Bahia.

are—settled by a large number of recent European immigrants. The exhibit of Rio Grande do Sul, the southernmost Brazilian state, adjoining Uruguay, is a revelation to every one who sees it. The writer's guide through this exhibit was a typical representative of the state. With French and German blood in his veins, but himself a thorough

Brazilian, he took enthusiastic and wholly justifiable pride in pointing out the variety of the products and the excellence of the workmanship exhibited in the collection of articles sent by his state. These include articles of clothing of all kinds, of silk, cotton, woolen, linen and leather: straw and felt hats; furniture; leather and canned goods; soaps, perfumery and drugs; glassware; pianos and musical instruments: preserves and pickles: cigars and tobacco; articles of horn: books; artificial flowers; furniture; papers; brushes; beer and wine; flour; crackers of all sorts. It is clear enough that European manufacturers will soon have to meet strong competition here in Brazil. As the writer's guide proudly said: "We make just as good biscuit, and just as many varieties, as the English do." The state of San Paulo, next south of Rio de Janeiro, makes an exhibit which is fully as complete and as varied as that of Rio Grande do Sul. On the other hand, we have the exhibit of that great northern state, Amazonas, whose name at once brings up vistas of immense tropical forests, with their precious woods of all kinds, and especially with their most precious rubber—the rubber which is causing so much jealousy about national boundaries in South America; the rubber to secure which men are being held in slavery as harsh and cruel, probably, as any slavery ever was in the world. An "Inferno Verde" the life of these rubber-collectors doubtless is. Such is the title of a recent book on this subject which is attracting attention here in Rio. Its cover-design is the figure of a naked Indian woman, bound hand and foot to a rubber-tree, her blood dropping out, from many wounds, into the little tin cups used in collecting the precious sap of the rubber-tree. The Amazonas exhibit gives a good opportunity to see how this famous—or infamous—rubber is collected and prepared for shipment. A rubber-tree, with a gash, and the little tin cup shows the first stage. Bottles of the milky sap, "rubber-milk" they call it, show the rubber as it came from the tree. This liquid is then carried to be smoked and dried; and is rolled up into great bales for shipment. One of these huge oval masses of rubber, weighing 800 kilograms, forms part of the Amazonas exhibit. All these steps are well illustrated by photographs. Amazonas is typical of the non-industrial states. It is rich in woods. The present exposition includes 200 specimens of these woods, ranging from those which are soft and light and porous, to the very dense and very heavy *pao ferro* (iron-wood). The brilliant feathers from the Amazon forests, wonderfully colored, would arouse the anger of our Audubon Society members, especially if they were told that many of these feathers go to the United States. Even Amazonas is not wholly destitute of manufactured articles, although they are few in number and mostly of a primitive kind. As one runs over the exhibits from the states situated successively farther and farther south, the industries increase, until, in San Paulo, Paraná, Santa Catharina and Rio Grande do Sul, they reach their maximum variety and highest development. Rich in promise for the future is the immense western state of Matto Grosso, across which a new railroad line has recently been surveyed, to connect the railroads of San Paulo on the east with those of Bolivia on the west. Matto Grosso sends to this exposition specimens of its sugar and farina and rice and corn; of its herbs; and of its woods, including the famous *quebracho* and shows, by means of photographs, some of its great herds of cattle. The state now has

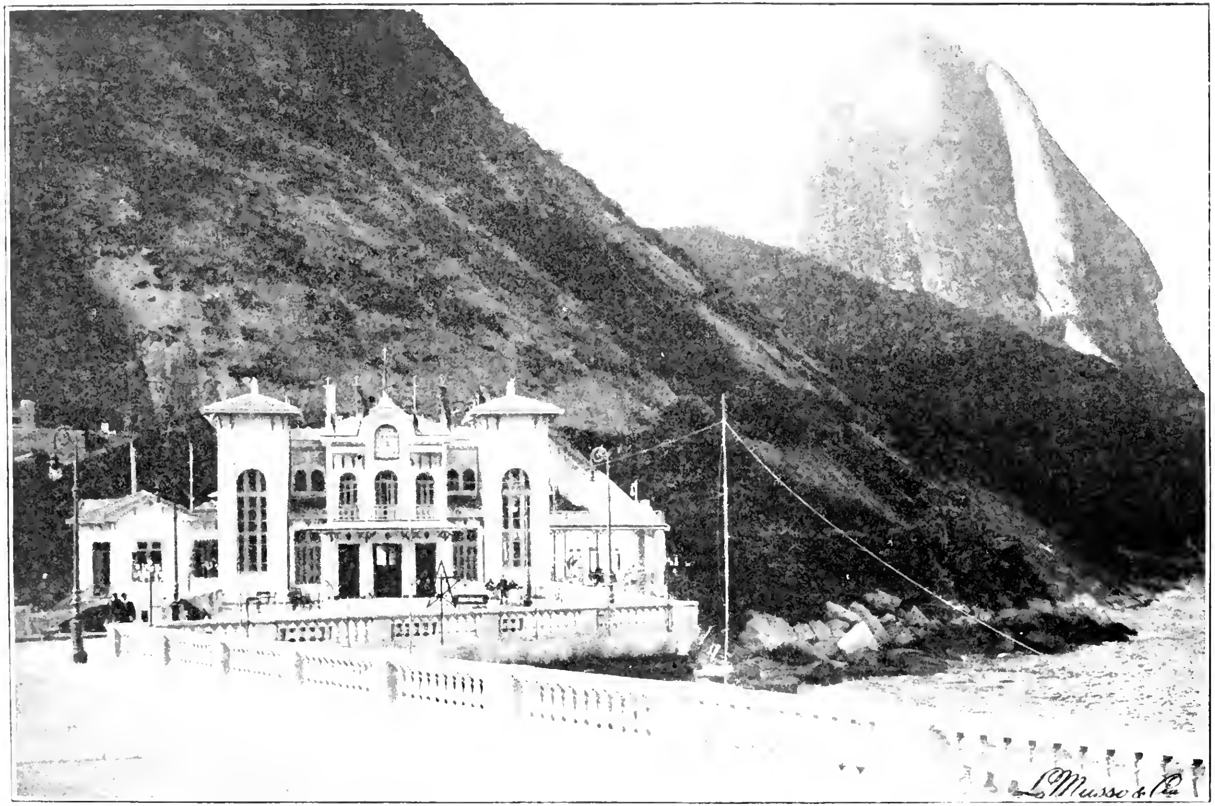


The Minas Geraes Building.

A stately and solidly constructed building, expressing the power and wealth of the great central State. It was designed by the Brazilian architect, Rebecchi.

3,000,000 head of cattle. Rio Grande do Sul has a fine exhibit of live cattle. Special mention may be made of the thoroughbred Durham and Hereford bulls, of which a considerable number are shown.

Whoever thinks of Brazil thinks of coffee, and whoever thinks of coffee-production in Brazil thinks of the state of San Paulo, the greatest coffee-growing district in the world. In the San Paulo exhibit the visitor will see bag after bag, and sample after sample, of coffee, of all grades, varieties, qualities, prices—confusing monotonous, if you will, but very instructive. A large diagram, hung on the wall, shows the export of coffee from Brazil in the year 1906–7. The total amount exported was 20,190,000 sacks, of 60 kilograms each. Santos, the world's greatest coffee port, exported 15,392,000 of these sacks. All countries outside of Brazil exported only 3,595,000 sacks. In this diagram these various amounts are represented by small coffee sacks, and each of the sacks of the diagram really represents 50,000 sacks of 60 kilograms each! Whether the traveler to Brazil can manage to get into the coffee district or not, he should surely not fail to see Santos. As the steamer comes up to the city through the narrow channel, winding about through green fields, one wonders where this famous coffee port is, of which every one has heard so much. You see some houses in the distance, very unattractive to the eye, and are told that is Santos. Your surprise continues to grow until, on making a final turn in the river you see, stretching out on your left, the famous Santos docks and warehouses, with steamers of all sizes and of many flags, lying two deep in many cases, the whole length of the docks. Everybody is busy. Teams, and mule-carts and donkey-engines and traveling cranes and porters—all busy loading coffee. Coffee is everywhere: in the streets, in the stores, on the train. If coffee is injuring the human race, Santos is doing its best to accomplish that purpose. From Santos to San Paulo there is a fine railroad journey up across the Serra do Mar; a steep climb, by cable road, to 2,500 feet above sea level. This trip should be taken by the late afternoon train. The contrast between the hot muggy air of Santos and the cool, fresh air on top of the Serra is then most striking and refreshing; the light on the mountains is then softest and most varied. The views down into the valley, with its many banana plantations, are very fine, and even the least observing traveler can not fail to notice the extraordinary precautions which have been taken to guard the line against washouts. The whole mountainside is actually walled up, in places, and everywhere are seen the brick and cement drains and ditches which carry off the rainfall. One of the engineers of this road says that the ideal for which he is striving is to know what will become of every drop of rain that falls on these mountain slopes! To maintain this line, in good order, is one constant struggle against the destructive action of



RESTAURANT "PÃO DE ASSUCAR."
The restaurant is situated at the northern end of the esplanade *Fraia Vermelha.* In the background is the Pão de Assucar (Sugar Loaf), one of the natural features of the exposition grounds.

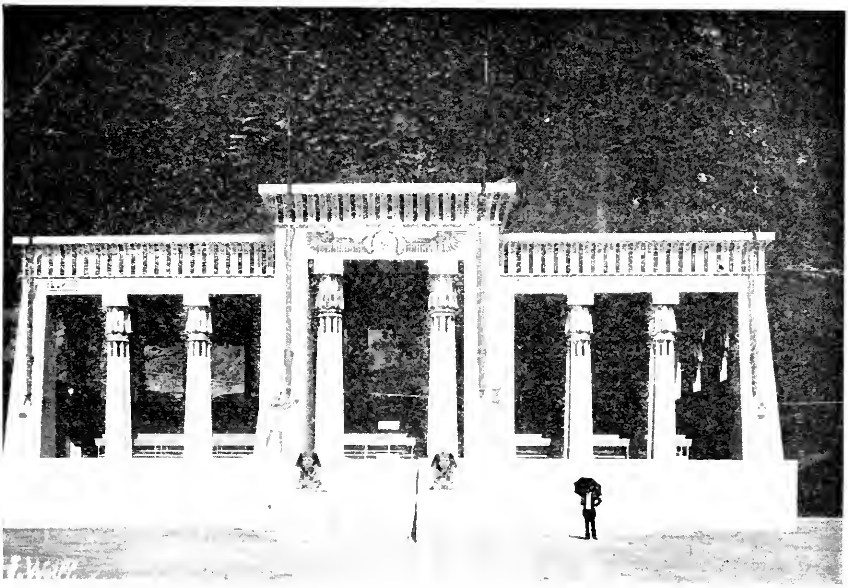
rain-water, which is flowing downhill—nothing more—and, unfortunately for the railroad, nothing less!

Another exhibit, mention of which is suggested by the above note on coffee, is that of maté. Barrels and bags and smaller samples of maté are seen best in the exhibits of the state of Paraná. The common name for maté, "Paraguay tea," associates this plant with Paraguay, but Brazil is becoming a more and more important maté-producing country. When white men came to these parts of South America, the Indians were found to be drinking maté, and the Jesuit missionaries soon discovered the excellent properties of the plant and forthwith adopted the native custom of using it. The maté tree grows to be 10 to 20 feet high; its natural habitat is on the plateaus 1,500 or more feet above the sea, and chiefly in Matto Grosso, Paraná and Paraguay. It is now extensively grown on plantations. Advocates of the use of maté as a drink, in place of tea and coffee, have gone very far in attributing to this herb medicinal, nutritive and stimulating qualities which would seem to make maté an absolute essential to health and happiness. The writer has before him at this moment a report on maté, made to a commercial and industrial body in Paraná a few years ago, and in this account the benefits to be derived from the use of maté tea are enumerated at great length. But whether these beneficial qualities are exaggerated or not, the fact remains that maté-drinking is very much on the increase, and that those who indulge in it are practically unanimous in stating that maté is far superior to tea, in not producing insomnia or nervousness. Americans who want to see a maté factory will do well to visit Curityba, the capital of the state of Paraná. There the "Fabrica Tibagy," one of the largest in Brazil, will be freely opened to their inspection. This factory exported last year 3,000,000 kilograms of maté, the whole amount exported from Paraná being 30,000,000 kilograms. The leaves and small stems are brought to the factory in burlap or rawhide bags, and after being thoroughly dried, in ovens, are passed through a screening process, which separates the stems and leaves, according to their size. The coarsest stems are used for fuel; the less coarse ones are sold for the cheaper grades of maté. The leaves are then carefully sorted, according to their quality, and are next run through crushing machines. The best maté is in the form of a very fine olive-green powder. Maté tea is prepared much like ordinary tea. It may be taken in a cup, if properly strained, but the native way is to leave the powder in the water and to suck up the tea through a tube provided at the lower end with a fine strainer. The taste of maté to the novice is not unlike that of a very weak solution of hot turpentine. It is therefore safe to say that maté-drinking is an acquired taste for those who are accustomed to ordinary tea. Most of the Brazilian maté goes at present to the

Argentine Republic, but some is already being exported to France. The visitor to Curityba should, by all means, going or coming—preferably both going and coming—take the trip by rail between Curityba and Paranaguá. This is without question one of the most picturesque railroad journeys in the world. From Paranaguá, on the coast, the railroad ascends the splendid range of coast mountains up to a height of about 3,000 feet above sea level, by a long series of curves, tunnels and bridges which are marvels of engineering skill. Bare rock, mountain torrent and waterfall, forested slope distant views over the deep valleys and plains below, follow one another in rapid succession for two hours. On the lowland and lower slopes you see, in the greatest profusion, oranges, bananas and sugar-cane. On the way up you pass through a densely-tangled forest, whose trees are almost completely covered with moss, creepers and parasitic plants of all kinds. Once across the top of the mountains you find yourself on a campo—rolling; sparsely wooded, very bare by contrast. Very few American tourists ever take this journey. But one can hardly be said to have seen anything of Brazil who has not been farther inland than the immediate sea-coast, and it is in the coast cities that most travelers spend their time.

American visitors to this exposition will be especially interested in the exhibit of the experimental rice farm at Moreira Cesar, in the state of San Paulo. On this farm, with the aid of irrigation, our fellow countryman, Mr. Wellman Bradford, of Louisiana, is carrying on an experiment station where students, selected by the government, are being taught scientific rice-growing. Mr. Bradford has had many difficulties to contend with in his work, but he has faithfully persisted in his undertaking, and deserves the greatest credit for his skill and perseverance. Japanese rice, which has lately been sown on this farm, has been found to give the best results as to quality of the crop. Another exhibit of interest to Americans is that of the model farm at Piracicaba, in the state of San Paulo. This farm is carried on, as is the rice farm just referred to, under government auspices. Its director was formerly at the Michigan Agricultural Experiment Station. Cereals of many kinds are raised, as well as cotton, rice, sorghum and alfalfa. Experimental plantings of various kinds of wheat and corn from the United States are being made, and the people who come to the farm are being taught modern methods of farming, and stock-raising. No more important work for the agricultural future of the country here in Brazil is being done than that now in hand at the rice farm at Moreira Cesar, and at the Fazenda Modele at Piracicaba.

The National Exposition at Rio de Janeiro, taken all in all, is immensely significant, instructive, impressive. It tells of the natural wealth of Brazil; of the variety of its products; of the many arts and industries that have here been developed almost wholly without the knowledge of the bulk of the people in whose midst the factories and mills and machine-shops have sprung up. It is fitting that this exposition should take place in celebration of the centennial anniversary of the opening of the ports of Brazil to the commerce of the world. The exposition finds its appropriate location in the new Rio de Janeiro, with its new avenues and boulevards, docks and warehouses, and the many other improvements which have changed it so recently into a modern city.



A BIOGRAPHICAL HISTORY OF BOTANY AT ST. LOUIS, MISSOURI. III.

By Dr. PERLEY SPAULDING

LABORATORY OF FOREST PATHOLOGY, BUREAU OF PLANT INDUSTRY,
U. S. DEPARTMENT OF AGRICULTURE

EXPLORATION in the Missouri country was commenced in 1835 by Karl Andreas Geyer, a collector who became well known for his botanical explorations in the northwestern section of the United States. His explorations extended over a number of years and ranged from Illinois westward to the Pacific. He traveled especially in the territory included between the Mississippi and the Missouri River as far north as North Dakota.

Karl Andreas Geyer[12] was born in Dresden, Germany, on November 30, 1809. His father was a market gardener of very moderate circumstances. The boy was naturally bright and studied Latin under the tutelage of a kind-hearted man who helped him with his lessons, which were studied while he was selling his father's produce in the streets of the city. In 1826 he entered the garden at Zabelitz as an apprentice. In 1830 he removed to Dresden and engaged as assistant in the botanic garden there. In this place he had numerous friends, among whom was Dr. H. G. Reichenbach, whose lectures upon botany he attended with great regularity. He seems to have been a very likable and attractive person, drawing the attention of those with whom he came in contact. In February, 1834, he left Dresden for America. Here he collected plants during the summer months and worked at odd jobs in the winter, thus maintaining himself for several years. In one case he entered a newspaper office as compositor, but a few months later he was writing the leading articles for the same paper that he had helped set in type.

Geyer's first great journey in this country was in 1835, when he visited and explored the plains of the Missouri with a single companion. In 1836 and the succeeding years he went with Nicollet surveying the country between the Missouri and the Mississippi River. In 1840 he collected around St. Louis and in Illinois, making very considerable collections during this season. While in St. Louis he became acquainted with Dr. George Engelmann and this friendship seems to have lasted as long as Geyer was in this country. Engelmann seems to have worked over his collections, as we find him publishing upon them

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[12] Anonymous, *Chronik des Gartenwesens*, 3: 185–187, 1853.
Reichenbach, H. G., *Kew Garden Miscellany*, 7: 181–183, 1855.

in 1844. He also came into possession of some of Geyer's collections, as it is definitely stated that they had been deposited in the Engelmann herbarium.

In 1841 Geyer went with Fremont to the Des Moines River in Iowa territory, where he found a number of new plants. In 1842 he explored the upper Illinois territory and formed the herbarium which was first offered for sale. In 1843 he began the journey from Missouri to the Pacific coast, lasting through the years 1843 and 1844. He explored the northwestern country very extensively and penetrated to hitherto inaccessible places by accompanying missionary trains on their visits to the different Indian tribes. He finally reached Fort Vancouver, and from there sailed on November 13, 1844, for England, going by way of the Sandwich Islands and Cape Horn. He arrived in England May 25, 1845, and spent some months at Kew, working over his collections and sorting out small lots of plants to sell. A large part of his profits from such sales was used in defraying expenses caused by a sickness brought on by his previous hardships. In September, 1845, he again returned to his home in Saxony, after an absence of eleven years. At first he entered the employment of head-gardener Lehman in Dresden, and later in the Royal Botanical Garden. His wanderings had shown him the value of a home, and on August 24, 1846, he married Miss Emma Schulze. Besides his duties for the garden he taught students the English language, his pupils coming from every class in Meissen. Geyer also took a prominent part in the local society for the advancement of science. During the last three years of his life he was editor of *Chronik des Gartenwesens und Feuilleton der Isis,* a periodical published at Meissen on the first and fifteenth of the month, from January 1, 1851, to December 15, 1853. Geyer's death occurred just before the end of the third volume, and it was discontinued with the third volume. While in no wise neglecting his duties at the garden, he came in written communication with the prominent botanists of the time and rounded out his collections. Heart disease troubled him considerably in his latter days and finally caused his death on November 21, 1853.

In 1835 a physician, George Engelmann by name, settled in St. Louis and soon built up a lucrative practise. During his spare moments he worked upon botanical problems, and before long he had established a reputation among botanists such that at his death he was ranked among the foremost of botanical workers.

Dr. George Engelmann[13] was born at Frankfort-on-the-Main, Feb-

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[13] Gray, Asa, *Proc. Amer. Acad. Arts and Sci.*, 19: 516–522, 1884.
Sander, Enno, *Trans. St. Louis Acad. Sci.*, 4: 1–18 (Supplement).
Anonymous, POP. SCI. MONTHLY, 29: 260–265. 1886.

FIG. 9. DR. GEO. ENGELMANN; by courtesy of the Director of the Missouri Botanical Garden.

ruary 2, 1809. He was the eldest of thirteen children. Aided by a scholarship he went to the University of Heidelberg in the year 1827, where he had as fellow-students and companions Karl Schimper and Alexander Braun. Political embarrassments caused him to go in the autumn of 1828 to Berlin University for two years, and finally to Würzburg, where he took his degree of Doctor of Medicine in the summer of 1831. His inaugural dissertation, "De Antholysi Prodromus," published at Frankfort in 1832, testifies to his truly scientific mind.

Trelease, Wm., and Gray, Asa, "Botanical Works of Engelmann," 1–548, 1887.

Sargent, C. S., "Silva of North America," 8: 84, 1895.

White, C. A., "Biogr. Mems. Nat. Acad. Sci., 4: 3–21, 1896.

It is a morphological study founded chiefly upon monstrosities, and it had the honor of receiving the notice and approval of Goethe, who offered to place in Engelmann's hands his notes and sketches, which intention was frustrated by his death before it had been carried out. This first paper has been very favorably commented upon, and compared with much more extended and pretentious works of a similar nature.

The spring and summer of 1832 were passed at Paris in medical and scientific studies with Braun and Agassiz as companions. He then became the willing agent of his uncles, who had resolved to make some land investments in the Mississippi Valley, and he sailed from Bremen for Baltimore in September. He joined some of his relatives who had previously settled in Illinois near St. Louis, and made lonely journeys on horseback through southern Illinois, Missouri and Arkansas. He finally established himself in St. Louis as a doctor of medicine late in the autumn of 1835. At this time St. Louis was a frontier town of eight or ten thousand inhabitants. Beginning in poverty, he soon built up a large practise and so established himself in his profession that he was able to go back to Germany for some months. While there he married his cousin, Miss Dora Hartmann, in June, 1840.

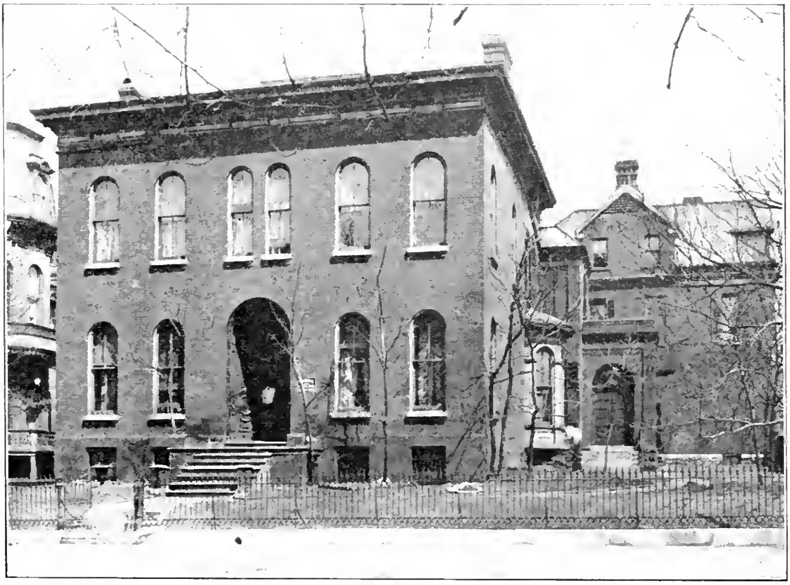

FIG. 10. RESIDENCE OF DR. GEO. ENGELMANN IN ST. LOUIS, MISSOURI: by permission of the Director of the Missouri Botanical Garden.

Again in 1856 he left his practise for a two years' absence, devoting the first summer to botanical investigations at Cambridge, and then visiting his native land in company with his wife and son. In 1868 the family again visited Europe for a year, the son remaining to study at Berlin. The mother died in January, 1879, and Englemann's own health failed alarmingly. A journey to Germany was taken in 1883 and the voyage was so beneficial that he was able to resume his botanical work. Serious symptoms soon caused him to return and the ocean voyage again proved very restorative and he resumed his labors with increased vigor. Increasing infirmities, however, gradually reduced his working powers until his death, which took place on February 4, 1884.

Upon first coming to this section of the country Dr. Engelmann traveled on horseback through southern Illinois and in Missouri and Arkansas; and during the latter part of his life he explored the mountains of North Carolina and Tennessee, the Lake Superior region and the Rocky Mountains and contiguous plains in Colorado and adjacent territories, thus being able to study in place, and with the acuteness of judgment which characterized his work, the Cacti, Coniferæ, and other groups of plants which he had investigated for years. In 1880 he made a long journey through the Pacific states, where he saw for the first time growing naturally many plants which he had described and studied over thirty years before.

Dr. Engelmann's papers are voluminous even for a man who could devote all of his time to botany; but it must be remembered that he had a large practise as a physician, which took most of his time, and that botany was taken up only in spare moments. When this is taken into account, together with the fact that he was also interested in other sciences (especially meteorology), their extent is nothing short of marvelous. The memorial volume of his papers published by Henry Shaw contains eighty-seven different papers of varying length. These have been grouped in this volume under the following headings or general topics: Cuscutineæ, Cacteæ, Juncus, Yucca and Agave, Coniferæ, Oaks, Vitis, Euphorbiaceæ, Isoetes, Miscellaneous, Lists and Collected Descriptions of Plants, and General Notes. It was the custom of Dr. Engelmann to take any scrap of paper and make notes upon it which might occur to him, together with sketches showing characters of the plant in hand. All such notes were at his death collected and mounted in a set of large books which are now in the possession of the Missouri Botanical Garden. These notes were so numerous that they made a library in themselves, filling sixty of these books.

His method of working was to take a single group of plants and work it out systematically so far as was in his power. His treatment of the genus *Cuscuta* in his first monograph of that group increased the number of species from one to fourteen without going west of the

Mississippi Valley. Seventeen years later, after an investigation of the whole genus in the principal herbaria of this country and of Europe, he published a systematic arrangement of all the Cuscutæ, giving seventy-seven species, besides a number of varieties.

Dr. Engelmann's authority upon the *Cactaceæ* was of the very highest. He established the arrangement of these plants upon floral and carpological characters. This work was carried on through a series of papers beginning with his sketch of the botany of Dr. A. Wislizenus's expedition from Missouri to northern Mexico, and continued in his account of the giant cactus of the Gila, in his synopsis of the Cactaceæ of the United States, and in his two memoirs upon the southern and western species contributed to the Pacific Railroad Reports and to Emory's "Report on the Mexican Boundary Survey." He had made preparations for a revision of at least the North American Cactaceæ, but upon his death much knowledge of this difficult group was lost.

His papers on the American oaks and the Coniferæ are of the highest interest, and are some of the best specimens of his botanical work; and the same is also true of his study of the vines. Nearly all that we know of this genus scientifically is directly due to Dr. Engelmann's investigations.

His work is characterized by a minuteness and carefulfulness of observation, coupled with a nicety of discrimination which made him a master in systematic work, his treatment of the yuccas and agaves, the genera *Juncus, suphorbia, Sagittaria, Isoetes,* the *Loranthaceæ, Sparganum* and *Gentiana* giving him an eminence among fellows botanists to which few attain. His name was upon the rolls of many societies devoted to the investigation of nature, and he was the recognized authority upon those departments of his favorite science which had most interested him. His name has been given to a monotypical genus of plants, *Engelmannia,* by Torrey and Gray. Numerous species also bear his name.

FIG. 11. NICHOLAS RIEHL; from a photograph kindly loaned by his son, Mr. E. A. Riehl.

Shortly after Dr. Engelmann settled in St. Louis, Nicholas Riehl.

a native of France, came to his city and settled on a piece of land on the Gravois Road in South St. Louis, and began to collect botanical specimens.

Nicholas Riehl[14] was born in Colmar, province of Alsace, France (now Germany), about 1808. His father's business was that of manufacturing cloth; not liking it, Nicholas sold it after the death of his father, and divided the estate. He took his share and traveled over much of Europe and America, coming as far west as St. Louis. Taking a liking to this part of the country, he returned to his old home and married. The two returned to St. Louis in the spring of 1836, and settled on a piece of ground on the Gravois Road in Carondelet, just outside the St. Louis city limits, and established a nursery. This is believed to have been the first nursery in St. Louis county, if not in the state of Missouri. The nursery business he carried on with success and profit until the time of his death in September, 1852. Riehl evidently collected botanical specimens some years before he came to this country, as specimens in his herbarium bear dates as far back as 1830, which were collected in the vicinity of Colmar. He also collected considerably in the vicinity of St. Louis in 1838. He had printed labels made for the collections made in this year, and they number not far from two hundred. Besides the specimens bearing the printed labels, there are many with incomplete labels which undoubtedly were collected here also. His entire collection was sold to Mr. Henry Shaw, who was at that time just starting to develop his botanical garden. The larger part of them were collected in Europe or were exchanged with European collectors. Mr. Riehl was a friend and admirer of Dr. George Engelmann, and was much interested in the work which he was doing. The Riehl nursery furnished Mr. Shaw the first trees which he planted in his newly started botanical garden.

In the forties Theodore C. Hilgard was collecting the native plants of the vicinity of St. Louis.

Theodore Charles Hilgard[15] was born at Zweibrücken, Rhenish Bavaria, on February 28, 1828. His father, Theodore Erasmus Hilgard, was a lawyer, who in 1836 resigned from the Supreme Court of the province and emigrated with his family to America, settling on a farm near Belleville, Ill., which at that time was the home of many other educated Germans who for political reasons had preceded him. Theodore was the sixth of a family of eight. The schools being poor and few in number, Theodore with the other younger children received his primary education from his elder sisters and elder brother Julius,

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[14] Information and photograph supplied by Mr. E. A. Riehl, of Alton, Illinois, son of Nicholas.

[15] This sketch is adapted with very slight changes from a manuscript kindly furnished by Professor Eugene W. Hilgard, brother of Theodore.

while all received their higher training, especially in the languages, from their father. The boys aided in the farming operations and Theodore early manifested a marked interest in the natural sciences, and especially in botany; in which, however, his father could not help him. He soon found an enthusiastic helper in his younger brother Eugene, and together they made extensive collections of the native plants and insects of the vicinity. Dr. George Engelmann, a second cousin, greatly assisted the boys in their botanical studies.

Early in 1847 Theodore went to Europe and entered the University of Heidelberg as a student of medicine. Henle, Chelius and Hasse then made Heidelberg the most notable center for medical study outside of Vienna, while Bischoff represented botany. Hilgard at once began to make what subsequently became a very complete collection of the flora of central Europe. The revolutionary agitation of 1848 somewhat disturbed the regularity of the course of study, but no actual interruption occurred until, in the spring of 1849, active revolutionary movements took place in Baden itself. Theodore then (with his brother Eugene, who had meantime joined him) went to Zürich, and there passed three semesters, studying especially microscopy under Naegeli, and physiology under Ludwig, besides attending the natural history lectures of Oken. During this time the brothers made extended excursions on foot through Switzerland and collected the Alpine flora. In 1851 Theodore went to Vienna to study, where were then such medical celebrities as as Rokitansky, Oppolzer, Bednar and Hebra. After nearly two semesters, during which he gave much time to botanical study in the great Endlicher collection, he was obliged to go to Malaga to bring back his widowed sister. While there he made an extensive collection of Mediterranean plants which greatly interested him. On his return he went to Würzburg, where he graduated in June, 1852, *summa cum laude,* as doctor in medicine, surgery and obstetrics. He then went to Berlin to study ophthalmology with Graefe, as well as surgery. In the summer of 1853 he returned to America, taking a position as ship physician on an emigrant vessel, on which he experienced an epidemic of cholera.

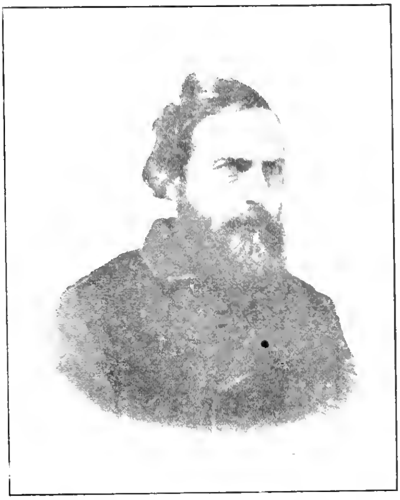
FIG. 12. DR. THEODORE C. HILGARD; by courtesy of Dr. Eugene Hilgard.

Soon after his arrival he went on a visit to the west to see whether he had best practise his profession there. On the way he sustained a severe shock to his spine in a steamer accident. It took him several weeks to recover somewhat, but he never fully recovered. He was disappointed in the outlook and returned to the east, where he took up practise in Philadelphia. There he became a friend of Elias Durand, a druggist and botanist, who in the latter capacity was requested to elaborate the botanical collections made by Heermann while with the Williamson Pacific Railroad Expedition. Durand proposed to Hilgard that they should collaborate in this work, and the latter being by nature an expert draughtsman, he not only described, but drew the illustrations of a large number of the "Plantæ Heermanianæ" accompanying the final report of the expedition. The strain of this work seemed to develop the spinal injury into a serious inflammation, from which he was prostrated for months. After recovery which was, however, never complete, he resolved to begin practise in St. Louis, and removed there in 1855.

He continued to practise in St. Louis from that time until 1870, much handicapped by the spinal weakness which obliged him to refuse much lucrative practice. His spare time was chiefly devoted to botanical studies, now more especially to the cryptogams, whose development he studied under the microscope, in the use of which he became very expert. In these studies he found that the then current classification and nomenclature of these organisms was seriously at fault, many merely developmental forms being classed as separate species, genera and even orders. He also worked zealously in devising a system of arrangement of the phanerogams which would express their mutual cross relations, the best graphic presentation of which on a flat surface he found in the pentagrammatic form. Comparative anatomy and the homotaxy of organs and structural parts also formed a favorite subject of investigation. Most of his work on these subjects was published in the *Proceedings* of the St. Louis Academy of Sciences, of which he was a charter member; also in the *Proceedings* of the American Association for the Advancement of Science and in the *St. Louis Medical Reporter*. He also helped in the organization of the "Humboldt Institute" library which for some time had a very useful cultural influence. In 1865 he married Miss Georgina Koch, daughter of Mr. A. Koch, of *Zeuglodon* fame. No children came of this union.

As the state of his health precluded his acting as an army surgeon, he remained at St. Louis during the war in hospital and private practise. After the war medical practise seemed to become more and more incompatible with his strength, and he gave it up and joined his brother Eugene at the University of Mississippi, where at that time a lectureship of botany was contemplated. But it failed of realization, and he accepted a position in the U. S. Coast Survey as observer in the magnetic survey then being made on the basis of the "Bache Fund." In this he continued until 1873, when he found it necessary to settle to a quiet life. The last year of his life was passed at New York City, where in March, 1875, he died of an abscess of the lungs.

The Hilgard collection of plants, embracing about 12,000 species, was taken by his brother Eugene to the University of California, where it was destroyed by fire in 1897.

Shumard in his presidential address before the St. Louis Academy of Sciences in 1869 spoke as follows concerning a collection of plants given by Hilgard to the Academy:

> Our botanical collection embraces an extensive series of lichens and mosses amounting to several hundred species, chiefly from western states and territories. These were collected by Dr. T. C. Hilgard, of this city, and by him presented and arranged in our museum.[16]

In the fire which destroyed part of the academy museum a few years later, this collection was also destroyed.

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[16] Shumard, *Trans. St. Louis Acad. Sci.*, 3: XII., 1869.

(*To be continued*)

THE LATEST CALABRIAN DISASTER

By Professor WM. H. HOBBS
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NOW that more reliable accounts have reached us of the terrible disaster to Calabria and Sicily, it is possible to discuss some larger facts which seem to be revealed with clearness. The grand eruption of Etna, the disappearance of the Eolian islands, and other equally improbable rumors, have ceased to be valuable scareheads in the newspapers. The death loss it is still too early to properly estimate, but on the basis of a well determined law of news reporting, it is safe to say that the larger of the estimates will be much reduced. Many that have been reported killed will eventually be classified among the maimed and wounded, and many communes now supposed to be in as great plight as their near neighbors, will be found either to have received but slight damage or even to have remained immune. Such has, at least, been the history of the earlier Calabrian earthquakes.

A number of large towns at first reported destroyed as a result of the Calabrian earthquake of September 8, 1905, the writer found on visiting them a few weeks later had escaped without injury of any kind. The reported death roll fell from many thousand to 3,000, then to 1,500, and finally to 529, the last figure, that of the official count by communes.

Yet, notwithstanding this history there seems no reason to doubt that the death loss from the recent shocks will mount far into the tens of thousands. The greatest of previous disasters from this cause within the same region occurred in February and March, 1783, at which time the death roll was 29,515 (as finally counted by villages) and the property loss $26,000,000. This was, however, one of the greatest earthquake disasters of history, for recent extended studies by Woehle have shown that Lyell's estimate of 60,000 for the deaths caused by the Lisbon earthquake of 1755 should be divided in half. In this instance the estimates of deaths which were made at the time ranged all the way from 25,000 to 150,000.

One can not read of the rush of Italy's king and queen to the succor of their pitiably afflicted subjects, and of their remaining among them with considerable danger to themselves, without realizing that there is much of the heroic in it. The traditions of an almost parental relationship to their subjects, have thus been well maintained through the inspiration of their presence and their magnificent personal courage. The actual conditions have been terrible enough, but apprehensions of phantom dangers flourish amid ignorance and superstition, and in Italy the inspiring example of the sovereigns is hardly less important to operations of succor than are the rescue corps and their supplies. It was the writer's fortune to follow somewhat closely in the footsteps of King Victor Emanuel and Queen Helena after the Calabrian earthquake of 1905, and again after the Vesuvian outbreak of the following year, on both of which occasions a similar impulse carried them at once to the afflicted districts. As a result of this experience the writer has only admiration for their conduct.

A further word may be added concerning the work of the troops which were then engaged in rescue operations, since their conduct has been unfavorably commented upon in some quarters. The writer had ample opportunity to observe their work and would submit that the army acted not only with vigor and effectiveness, but upon a thoroughly scientific plan. There is, therefore, every reason to believe that all which is possible will be done by the Italian government in the face of the much greater catastrophe which it is now facing.

It is, however, beyond Italy's power to properly meet this disaster without some help from the outside world. The first supplies of food and of hospital stores, it may be expected, will be contributed in sufficient quantity, for the horror of the event has stirred the entire western world. The greatest pinch of poverty and starvation will come when the great wave of emotion has passed and the future alone is to be considered. To properly appreciate this, it is necessary to consider the normal economic conditions and the recent physical history of southern Italy.

Calabria and northeastern Sicily, the provinces affected by the earthquake, are overpopulated, and from them there has been much emigration to the United States and to South America. The chief sources of income are the culture of the olive, fig, the citrus fruits, and the cereals, and in Sicily the mining of sulphur. As regards fruit and cereal culture, the peculiar conditions of farm tenure are such that even under favorable circumstances a large part of the population is kept on the verge of poverty. The sulphur mining in Sicily is carried on in a small way over most of the interior, and until a few years ago was a fairly profitable industry. Now, however, the use of pyrites as a substitute for sulphur in the manufacture of vitriol, and the recent successful exploitation of the vast sulphur deposits of Louisiana, have so reduced the price of sulphur as to threaten the only means of livelihood of a large part of the Sicilian population.

In contrast to southern Italy, the conditions of living in the northern provinces are good, and it has long been necessary for the north

Italians to contribute to the support of their compatriots in Calabria and Sicily. As a result of this burden, a strong party in the government has long been advocating a separation of the two sections, which would leave Calabria and Sicily to care for themselves.

To these discouraging general conditions must be added a series of special calamities which have befallen southern Italy since the summer of 1905. In September of that year, without warning of any kind, came the blow of the great Calabrian earthquake, the shocks of which destroyed property to the value of nearly $10,000,000, besides leaving a long list of killed and wounded. Both government aid and large private subscriptions from the northern provinces were necessary in order to succor the victims and in part to rebuild the ruined villages.

In the following spring heavy rains largely ruined the crops in Sicily, and in April occurred the great eruption of Vesuvius which spread a mantle of ash on the flanks of the mountain, so as to bury the vineyards and remove for some years the sources of livelihood. Many thousand people who dwell upon the flanks of the volcano were thus thrown upon the government for support and the more favored Italians in the northern provinces were obliged to make further sacrifices for their relief.

What, we ask, is Italy to do in the face of the new disaster, following as it does so swiftly upon the heels of the others, and dwarfing them by its proportions. It avails nothing now to argue that much of the loss of life and property might easily have been avoided, had buildings suited to such a seismic district been constructed. This fact has again and again been pointed out by properly qualified persons after each fresh disaster, but the force of inherited tradition is not so easily turned aside, and it was only after the earthquake of 1905 that the beginning of better things was seen. Then in place of the loose stone and tile houses—veritable man deadfalls—which have again and again been raised over their own ruins, strong wooden barracks were constructed under government supervision. It is, however, only in such towns as were largely destroyed in 1905 that such reform measures have been adopted.

Leaving now the humanitarian side of this calamity we may turn to its scientific aspects. Enough is already known to state that the site of the heaviest movement lay in and about that small arm of the Mediterranean which separates Sicily from the mainland of Italy—a section of crust, therefore, which immediately adjoins upon the west that which was heavily shaken in the fall of 1905. This fact, no doubt, helps to explain the otherwise exceptional character, since a destructive earthquake is apt to be followed by a rather long period of comparative quiet, so soon as the so-called aftershocks have faded away. The great earthquake of 1783 possessed likewise this double character, but in that instance also the areas of the heavy shocks were distinct though adjacent.

For purposes of study the latest Calabrian earthquake appears to offer some exceptional opportunities. The peculiar outlines of the two land masses which are involved render them specially open to study from the sea as a base. The full importance of this fact will be appreciated by any one who has been compelled to find accommodations where only the ruins of hotels exist. Under such circumstances one must proceed on foot or with a donkey, carrying supplies of bread and wine with him.

A scientific party engaged in studying the Calabrian earthquake could live for most of the time upon a vessel from which the shore would be reached either at the numerous ports or by launches. If a government vessel is to be sent with supplies to the afflicted district, the opportunity should not be lost to despatch a scientific party aboard her.

For another reason the recent earthquake offers unique opportunities for study. It has long been known that the straight eastern coast line of Sicily corresponds to a great zone of faulting within the earth's crust, and more than once in the past the slips upon it have brought disaster. On at least one such occasion, the sea bottom between Messina and Reggio and between Charybdis and Scilla has been considerably modified. In the vicinity large strips of cliff have slipped down into the deep sea at their base. A primary object of a scientific party charged with the investigation of this earthquake should, therefore, be to carry out an elaborate series of soundings in waters within and about the straits of Messina. Fortunately the dangerous nature of this channel is responsible for accurate data which represent the late condition. We have, therefore, here the opportunity of determining by a simple re-survey the changes which are ascribable to the recent earth disturbance.

A second section of the expedition should have for its chief object the preparation of maps of all portions of the shores or inland areas which reveal any change of configuration as a result of the earthquake. One of the most difficult of questions which arise in connection with earthquakes is to determine the exact significance of the so-called "secondary cracks." These cracks are generally found in loose materials, and the question is in how far they represent the projection upon the earth's surface of cracks within the consolidated rock below, or in how far they are due to settlement, and have in consequence less significance of orientation. This question can be definitely settled only by the aid of careful and detailed maps, which are studied in connection with the fracture system of the more firmly consolidated rocks.

Either the same or a separate triangulation section of the party should have charge of the re-occupation of primary triangulation stations in order to see what changes in position and elevation of these stations are properly ascribable to the earthquake. It may well be doubted if more ideal conditions could anywhere be found for such a study. If continued changes should be found to occur during the progress of the surveys, as is by no means improbable, the opportunity thus offered to compare mass movements of the ground with the time of prominent aftershocks should be regarded as of the first importance.

In every great earthquake which is studied, perhaps the most important line of attack is found in the distribution of the surface intensity of the shocks. It is now everywhere acknowledged that this intensity or amplitude of movement (and it is on this that damage to structures depends), is in a large measure determined by the elastic or non-elastic nature of the underlying material. Amplitude of movement is least on so-called "solid rock," it is greater on non-coherent deposits such as alluvial material, and it is probably greatest over so-called "made ground," with its tin-can and crockery ingredients.

With the passing of the centrum theory it is inevitable that the study of the immediate basement of each locality should enter upon the quantitative stage of development. The local quantitative effect of the surface layers is a factor which to an approximation may be known and for this reason should be eliminated, if the seats of movement are to be determined. Local thickness and relative elasticity of the unconsolidated materials in the basement must therefore, be determined, and the value thus obtained be deducted from the total local intensity, if we are to arrive at the genesis of the disturbance. Accurate geologic maps and earlier detailed seismological studies in Calabria and Sicily are favorable to an extended study of this subject.[1]

There are few, if any, places where within a circumscribed area more elaborate magnetic observations have been carried out than about the straits of Messina. Before the earthquake of 1905 a detailed magnetic survey for this district had been completed. It is almost certain that large changes would be revealed by a new survey since it has been shown in Japan that important changes in the isomagnetics resulted from the great earthquake of 1891. The importance of magnetic records to earthquake study is each year being made more apparent.

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[1] William H. Hobbs, I., "On Some Principles of Seismic Geology," with an introduction by Professor Eduard Suess; II., "The Geotectonic and Geodynamic Aspects of Calabria and Northeastern Sicily," with an introduction by Count de Montessus de Ballore. Gerland's "Beitraege zur Geophysik," Vol. 8, 1907, pp. 219–362, pls. 12.

A sixth object of study should be the tsunamis or "tidal waves" which apparently followed upon the recent shocks, since it has been demonstrated that such waves go out from the deeps of the sea apparently as the result of movements upon the floors of those deeps. That these movements are not directly connected with the land disturbances is apparent in their absolute lack of relation to such disturbances, even when the land disturbance is localized at and near the border of the sea. The California earthquake of 1906 was followed by no afterwave, though the Yakutat Bay (Alaska) earthquake of 1899 was succeeded by an inundating wave over forty feet in height.

Great deeps of the Mediterranean occur both to the north of Sicily (the Tyrrhenean deep on the site of a former land area) and also to the southeastward in the Ionian depression. Fortunately the land areas form a barrier between these deeps and furnish unusual opportunities of localizing the sea floor movements on the basis of the shore lines which have been washed by the wave. A series of soundings in these deeps, which have been already surveyed with considerable care, should afford a confirmative determination, provided changes not ascribable to errors in either series of soundings should be discovered. Such a discovery would certainly take foremost rank among earthquake investigations.

To sum up, therefore, it may be said that the proposed scientific expedition should be prepared to carry out at least six separate lines of investigation, since conditions are in all cases unusually favorable for study. These lines are: (1) a re-survey by soundings of the sea bottom separating Sicily from Calabria; (2) the preparation of precise and accurate maps by expert topographers of all sections of the land which have suffered noteworthy visible deformation; (3) the re-occupation of primary triangulation stations in the vicinity of the straits of Messina in order to determine changes in location and elevation; (4) the distribution of the damage on the land with due regard to the depth and character of superficial deposits, and further comparison of the results with those of earlier quakes within the same district; (5) a magnetic re-survey of the near shores (unless this is to be carried out by Italian workers); (6) the taking of a sufficient number of soundings over the great Tyrrhenian and Ionian deeps to determine whether changes in depth explain the after-waves of the earthquake.

As precedent for such studies conducted upon foreign soil, it should be stated that the great Andulusian earthquake of Christmas Day, 1884, was studied by a French Commission headed by Professor F. Fouqué, sent out by the Paris Academy of Sciences. The same disaster was also successfully investigated by an Italian Commission sent by the Royal Academy at Rome, and our present knowledge of this earthquake is very largely based upon the monographs which were published by the French and Italian Commissions.[2] There is, moreover, every reason to think that the Italian government would welcome and cooperate in every way with such an expedition as is here proposed. The present writer takes pleasure in saying that his studies of the Calabrian earthquake of 1905 were aided in every possible manner by the Italian scientific societies, and by individual seismologists.

There is a further reason why such a study should be undertaken by outside parties. It is difficult for one unfamiliar with the facts to understand the vexatious delays under which Italian scientists are often compelled to carry out their work. As a result of the financial straits in which the Italian government finds itself, the publication of scientific monographs is often long delayed. The manuscript of a report upon the Calabrian earthquake of 1894 had not seen the light when the shocks of 1905 arrived. This greater catastrophe seemed to render the report of less vital importance than a new report, and two separate royal commissions were appointed to prepare a report upon the disturbance of 1905. As their report has not yet appeared it is likely to be side-tracked for the report upon the new disaster. Thus the results of much painstaking scientific work see the light only in brief abstracts, because government action is too slow or, shall we say, seismic action too frequent.

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[2] F. Fouqué et al., Mission d'Andalousie; "Etudes relatives au tremblement de terre du 25 décembre 1884 et a la constitution géologique du sol ébranlé par les sécousses," *Acad. Sci. Paris, Mem.*, 2me ser., Vol. 30, 1899, pp. 1–772, pls. 42. T. Taramelli e G. Mercalli, "I terrimoti andalusi cominciati il 25 dicembre 1884," *Atti della R. Accad. dei Lincei, Mem.*, 4th ser., Vol. 3, pp. 116–222, pls. 4.

JEFFERSON DAVIS'S CAMEL EXPERIMENT

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WHEN Jefferson Davis was secretary of war he inaugurated an interesting and important experiment for the purpose of determining whether camels could be used for transportation purposes in the United States. Never before or since that decade preceding the Civil War has the government been confronted with such serious problems as were caused by the territorial expansion of the late forties, and of these not the least serious were the difficulties of communication and of transportation on the far western frontiers. Even before the annexation of Texas, New Mexico and California it had been a difficult task to administer government on the outer frontier; after the Mexican war the troubles were multiplied. Immense territories had been added, the frontier was more than doubled in length and was more exposed and dangerous; much of the unsettled region was mountainous, or was dry and without grass and water for pack animals and cavalry horses. The settlements on the Pacific coast also had a frontier—an eastern frontier which had to be guarded as well as the western frontier on the other side of the mountains. And for political and military reasons it was necessary that communications between California and the rest of the United States be made shorter and safer. The experiences of the army officers, especially those of the Quartermaster's Department, during the Mexican war caused them to turn serious attention to the question of transportation. On account of the rough or desert character of much of the country it was not possible to make much use of horses and packmules. Railroads, it was thought, would not for years traverse any of this country, and would never open up all of it. A formidable danger to frontier settlements, to small army garrisons and camps, and to communication of any kind, lay in the attacks of the hostile Indians of this region who, on their swift ponies, could make sudden raids and escape capture by the foot soldiers or the small bodies of cavalry.[1]

That the camel would suit such conditions was the belief of several army officers and particularly of Jefferson Davis, who when a young man had served in the army on the western frontier and later had commanded a regiment in the war with Mexico. The camel could travel faster than a horse and carry heavier loads over rougher ground, could go without water for days at a time and could live upon the poorest

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[1] See Reports of Secretary of War, 1853–7.

forage. It could also endure better than the horse or mule the extremes of heat and cold in this western region. The experience of other peoples had proved the value of the camel. In northern Africa and over the greater part of Asia the animal had always been the beast of burden—the most important agent of transportation. In climate and physical geography our western frontiers were similar to the regions which were the home of the camel.

Camels had been used in America, but not in large numbers. The Spaniards had imported them into Cuba and South America for use in transporting ore from the mines to the coast, but this experiment had not been a success. In 1701 some camels were brought to Virginia, but nothing more is known of them. In Jamaica, where the English tried them, the "chigger" or "chiqua," an insect which infested the feet of the negroes, got into the feet of the camels, rendering them unserviceable.[2]

The proposal to substitute camels for mules, horses and oxen in transporting supplies for the army was first made by Major George Hampton Crossman, a graduate of West Point, who was Zachary Taylor's quartermaster in the Seminole war. The difficulty of transporting supplies in Florida caused him to suggest that camels be introduced and used for that purpose. He made a study of the subject, and twenty years later was considered one of the authorities concerning camels.

Prominent among the officers who took an interest in the matter was Major Henry Constantine Wayne, a Georgian, who during and after the Mexican war, served in the Quartermaster's Department. He, with Senator Jefferson Davis, late colonel of the Mississippi Rifles, made extensive studies in regard to the different breeds of the animal, its habitat, the proper care of it, and its adaptability to the arid plains of Texas, New Mexico and California. Wayne, in 1848, made a formal recommendation to the War Department that camels be imported for experimental purposes, and Davis, who was on the military affairs committee, undertook to get an appropriation. In March, 1851, he proposed to insert in the army appropriation bill an amendment providing the sum of $30,000 for the purchase of fifty camels, the hire of ten Arabs, and other expenses. In support of his measure he made a speech reviewing the history of the camel as a servant of man and explaining the need for the animals in the west. There they would be valuable, he said, not only because of their burden-bearing capacity and their ability to live long without water and to eat scraggy bushes, but because of their greater speed. The dromedaries, or swift camels, could be used to mount cavalry and could carry small cannon, as had been done in Persia and in Egypt. Senator Ewing at first objected that the climate in the mountainous parts of the west was too cold for

[2] Leonard, "The Camel," pp. 1–18; Marsh, "The Camel," chap. 16.

the animal, but Davis convinced him that camels were useful in parts of Asia where the extremes of heat and cold were greater than in the west. Senator Rantoul objected that the proposition was extravagant and others that it was ludicrous. The appropriation was not made.[3]

A year later, when Davis had returned to Mississippi, Bissell, of Illinois, introduced into the House a bill carrying a $20,000 appropriation for the purchase of camels. Both Evans, of Maine, and Shields, of Ohio, who supported the measure, spoke of it as originating with Davis. The remarks made show that the War Department had considered the matter carefully and favored the measure. The house passed the camel bill but it was lost in the senate.[4]

By this time the public was becoming familiar with the proposal to import camels and numerous suggestions were made to the government. John Russell Bartlett, the author and ethnologist, who for three years (1850–1853) had worked on the southwestern boundary, was of the opinion that camels should be used in that region. George Robins Gliddon, the archeologist, who had lived in Egypt for twenty-three years, wrote a memorial to congress declaring that the project was feasible. Another eminent person, who was exerting himself to get the government to make the experiment, was George Perkins Marsh, the philologist and diplomat, who had lived in the Levant and who was acquainted with the camel in Turkey and Italy. To help the cause he delivered a lecture in 1854 at the Smithsonian Institution and also wrote a little book which was published in 1856: "The Camel, his Organization, Habits and Uses, considered with reference to his Introduction into the United States."[5] The general interest in the camel project caused the organization of "The American Camel Company," of New York, which proposed to import burden camels for use in the west. About 1857 the company landed one shipment in Texas, but nothing is known of further activities.

In 1853 Jefferson Davis returned to Washington as secretary of war and at once took up the question of importing and experimenting with camels. He had already made extensive researches into the history and habits of the camel when a member of the senate committee on military affairs. Now Major Wayne, of the Quartermaster's Department, and Lieutenant Beale and Captain Adams, of the Fort Yuma post, were directed to prepare information with reference to the use of camels on the western deserts. In his report at the end of the year[6]

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[6] House Ex. Doc., No. 1, 33 Cong., 1 Sess., p. 24.

[3] *Cong. Globe*, 31 Cong., 2 Sess., March 3, 1851. See Marsh, chap. 17, and Leonard, p. 15, in regard to Napoleon's camel corps and Wayne's translation of Columbari's Zemboureks about the Persian dromedary artillery.

[4] *Cong. Globe*, 32 Cong., 1 Sess., August 28, 1852.

[5] Marsh, "The Camel," chap. 17, on Introduction into the United States, and chap. 17, on Military Uses of the Camel.

Davis made a strong recommendation to Congress in favor of an experiment. He went into details about the great extent of newly acquired territory, its lack of navigable streams and of good roads, and the absence of grass and water for long distances. With horses, mules and oxen long circuitous routes had to be followed; the cost of transportation alone in this region was for one year nearly half a million dollars; and Indians made attacks and escaped because they could not be followed into the deserts and mountains; moreover, the Pacific coast, 120 days distant, was defenseless and for that reason quicker and better transportation must be provided.

Congress refused to make the desired appropriation and in December, 1854, Davis renewed his request for money to make the experiment. When the army appropriation bill was reported it carried no appropriation for the purchase of camels, but Senator Shields of Illinois and some western representative secured the amount of $30,000 for this purpose. The bill became a law on March 3, 1855, and Davis at once proceeded to send for the animals.

The camels could be procured only from the Levant. The mission to the Orient was first offered to Major Crossman, who nearly twenty years before had first suggested the use of camels. He declined, and Davis sent Major Wayne and Lieutenant David D. Porter of the Navy. Wayne was to go to England and France to secure further information about the camel, and Porter was to take the storeship *Supply* to the Mediterranean and meet Wayne at Spezzia. Davis furnished Wayne with a digest of all that was known about the camel and his letters of instruction show that the secretary possessed full knowledge of the subject.

Wayne visited first the Zoological Gardens in England and reported that camels had been reared there under such conditions that he was certain of success in the United States. Next he went to Paris to consult with the French officers who had made use of camels in Algeria.[7] From the information secured he decided that the African camel would not succeed in America as well as the Asiatic. He adopted the following classification: The Bactrian was the large two-humped animal, the Arabian the one-humped, and the "dromedary" was merely a swift Arabian, not a burden camel. These were points then confused by naturalists.

Meanwhile Lieutenant Porter had gone ahead and inspected at Pisa the camel herd of the Duke of Tuscany. These were descendants from Egyptian stock and had been used in Italy for two hundred years. There were 250 of them, Porter wrote, and they performed the work of 1,000 horses—some of them carrying as much as 1,200 pounds at a load; but he considered them overworked and badly cared for.[8]

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[7] See Marsh, chap. 17.

[8] See Leonard, p. 13.

After Wayne and Porter met at Spezzia they decided to get a camel at once in order to study its habits and to learn the proper treatment. They went in the *Supply* to Tunis, where Mohammed Bey gave them two animals which they hoisted on board, and proceeded to the Asiatic coasts, studying on the way the habits, ailments and care of the animals. Their observations were carefully reduced to writing and sent to Davis. The first stop after leaving Tunis was made at Smyrna, where they found fine burden camels, but no dromedaries such as Davis was anxious to get for chasing the Indians; at Salonica, the next stop, there were no camels—from both places the dromedaries had been taken for use in the Crimean war then going on. Davis had instructed Wayne and Porter to go to Persia to see about the Bactrians of that region, but at Salonica they found that the roads were closed by snow—it was now December—and that the country was in an unsettled condition. So after sending circulars to the English-speaking missionaries, consuls and business men in the Levant requesting information, the two officers sailed to Constantinople and thence went to the Crimea to see what was being done there with the camels. Wayne reported that the Bactrians seemed to be of little use because they were slow and because of their two humps, which made it difficult to fasten on the loads. But the one-humped Arabians were valuable; 3,000 were already in the Crimea and more were to be imported for the next campaign. The English officers who had used them in India were enthusiastic.

At Constantinople Wayne was disappointed in not getting a supply of both kinds of animals. All there were worthless or had the "itch." The Sultan sent far into the interior for good ones to give them, but Wayne, anxious to go to Egypt, did not wait for them to be brought to Constantinople.

The *Supply* sailed to Egypt and while Wayne went to Cairo to get permission to export dromedaries Porter remained at Alexandria looking over the market and making a lengthy report to Secretary Davis. He was now an enthusiast on the subject of camels. "I hope to see the day," he wrote, "when every Southern planter will be using the animal extensively." The education of Wayne and Porter progressed rapidly. They were soon expert camel traders. Animals at first palmed off on them as good they were now able to pronounce worthless. These they got rid of—two, for instance, they sold to a butcher in Constantinople for $44. Porter said "the good condition of these camels recommended them to a butcher of Constantinople, who bought them for purposes known only to himself." The natives now could not impose upon the ignorance of the American officers.

An amusing incident happened in Egypt. Wayne found it difficult to get permission to carry camels out of the country. He wanted twenty dromedaries; but could get permission to carry out only two. After protest this number was increased to four and later to five. Somewhat disgusted, Wayne started to leave Egypt, but the viceroy notified him that he would present six camels to the United States government. After delay the animals came. Porter after looking at them wrote an indignant letter refusing to accept the gift. They were "worthless and diseased," he said, and "I can not conscientiously receive them." The attempt of the Egyptian officials, he said "fraudulently to force a present on us" was a "discourtesy" to the United States which he would not tolerate. The viceroy laid the blame upon his servants and finally six good dromedaries were secured. Only three others were taken on board here, and the *Supply* sailed for Smyrna to complete the cargo.

The loading of the camels was done under Porter's supervision. Before leaving the United States he had prepared a "camel deck" or stable on the lower deck and had cut through the upper deck to secure a constant supply of fresh air for the animals. To get them on board he constructed a long flat-bottomed boat which could be run ashore. On this was a strong car with wheels which could be pulled out on land to receive the camels who often had to be dragged into it, and then the car was rolled back on the boat. From the boat the car holding the camel was hoisted into the ship and let down to the "camel deck."

While in Alexandria waiting for the viceroy to act, Mr. G. H. Heap, an American who had lived in Tunis and who accompanied the expedition, was sent on ahead to purchase other camels and equipments. When the *Supply* reached Smyrna, on January 30, 1856, Heap had the camels, saddles and other supplies ready. They were taken on board and on February 15 the *Supply* was turned toward America. The cargo consisted of thirty-three camels: nine dromedaries (Arabians) from Egypt; twenty Arabian burden camels; one young Arabian camel; two Bactrian (two humped) males; one Booghdee or Tuilu, the offspring of a Bactrian male and an Arabian female, having one hump.

Before leaving Smyrna the females that were not already with young were covered by the males, since it was the rutting season, and it was desired to increase the herd as fast as possible. To take care of them four Americans, two Turks and three Arabs were brought along—all under the supervision of Albert Ray, an army wagon master.

During the return trip, which lasted three months, the weather was rough. Wayne and Porter had been requested by Davis to stop at the Canaries[9] to see the camels there, but they were prevented by heavy winds. Wayne occupied himself in writing a long report to the secretary of war and in translating French works relating to camels. He wrote Davis that the information furnished by the letter had been generally accurate. The report gave a detailed history of the camel, an

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[9] See Leonard, p. 13.

account of the different breeds, their habits and usefulness, the nature of their diseases, the location of the best stock, the cost, the proper food and the methods of transportation. One of the papers translated was by Linant Bey, a French engineer in the Egyptian service, on "The Egyptian Dromedary"; one by General J. L. Carbuccia on "The Use of the Camel in Algiers." A paper by Colonel F. Columbari entitled "The Zemboureks, or the Dromedary Field Artillery of the Persian Army," had been translated and illustrated by Wayne in 1854.

During the voyage the animals were under the direct supervision of Lieutenant Porter, who interested himself in the minutest details. On the camel deck he posted detailed regulations to be followed in the care of the camels. A "journal of the camel deck" was kept, and in it every day wagon master Ray made note of every item of interest concerning the animals, their ailments, feed, appetites, when they were rubbed, curried, oiled, salted, etc. Some of the names are given: Said, Ayesha, Gourmal, Ibrim, etc. The first young camel born on board the ship was dubbed "Uncle Sam" and was trained by one of the Turks as a Pehlevan, or wrestler. Four of the grown camels were Pehlevans. Camel fighting was as much an oriental amusement as horse racing was a Kentucky sport, and Porter thought that the Americans might in time come to like camel contests.

When the weather was stormy and the ship unsteady there was danger of the animals falling on the smooth deck and injuring themselves. To prevent this Porter fashioned a sort of harness for each one and in rough weather made them kneel and strapped them to the deck. Once they were so strapped down for seventy-two hours.

During the voyage six calves were born. Of these only two lived; the others were probably killed by the ministrations of a quack Turkish camel doctor on board. Porter took care of the young camels as if they had been children, and gravely wrote to Davis about their diet, appetite, health, etc. Soon he was a better camel doctor than the Turk and the latter was superseded. To the secretary of war Porter sent some of the Turk's prescriptions: For a cold give the camel a piece of cheese; for swollen legs, tea and gunpowder; cauterize frequently for skin diseases; and for other complaints tickle the camel's nose with a chameleon's tail, or boil a young sheep in molasses and administer half of the mixture while hot. No wonder Porter was certain that Americans could manage camels better than the Asiatics.

At Kingston, Jamaica, a stop was made and great numbers of visitors came on board to see the camels—in one day 4,000 came. But here the camels suffered so much from heat that departure was hastened.

On April 29, 1856, the store ship reached Pass Cavallo, off Indianola, where, it was planned, the camels were to be landed. But the sea was so rough that the transfer to lighters could not be made. Porter then sailed to the Balize, the southwestern mouth of the Mississippi

River, and there on May 10 he transferred his cargo to the steamer *Fashion* under Major Wayne. Four days later Wayne landed the cargo at Powder Point, three miles below Indianola. The animals were in good condition notwithstanding the long confinement—one of them had been on board nine months. "On being landed, and feeling once again the solid earth beneath them," Porter wrote, "they became excited to an almost uncontrollable degree, rearing, kicking, crying out, breaking halters, tearing up pickets, and by other fantastic tricks demonstrating their enjoyment of the 'liberty of the soil.' Some of the males becoming even pugnacious in their excitement, were with difficulty restrained from attacking each other." The Texans were greatly interested in the camels and Porter wrote later to Davis that "perhaps the love of amusements may render the importation of camels in Texas popular if their utility does not recommend them." He meant that the Texans might possibly take to camel fighting.[10]

Less than one third of the appropriation had been expended and Davis determined to send at once for a second cargo of camels. Wayne was again offered command of the vessel, but he preferred to remain in Texas to conduct the experiment. Major Crossman also declined to go. Finally Porter and Heap were sent. Before leaving Porter carried to Davis the "Camel Deck Journal," his letters rejecting the camels offered by the viceroy of Egypt, and some drawings of camels in harness made by Mr. Heap. Porter arrived at Smyrna in November, 1856, where he found that Heap, who had gone on ahead, had collected a number of young camels. The six dromedaries presented by the Sultan had been sent to Smyrna and these with the others were taken on board. On November 14 the *Supply* again set sail for Texas. On board were forty-four animals: Two Bactrian males; three Arabian males; one Tuilu, cross-bred, male; one Tuilu, cross-bred, female; thirty-seven Arabian females.

The second voyage homeward lasted eighty-eight days and was rougher than the first. For thirteen days at one time the camels were strapped to the deck. But only three died during this voyage and Porter turned over to Captain Van Bockelen, quartermaster at Indianola, forty-one animals in good condition. There were now seventy in the herd, five of the first number having died since reaching Texas.

Meanwhile, during the summer of 1856, Wayne had been testing the value of the camel as a burden bearer. Certain of success, he wanted to breed camels until the herd was large, but Davis wanted to ascertain first whether they would be useful. For a few days the animals rested at Indianola. The Texans refused to believe in their burden bearing capacity, so one day Major Wayne had two bales of hay, weighing 314 pounds each, loaded on one of the males; the spectators were sure that

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[10] The documents in regard to the expedition are in Sen. Ex. Doc., No. 62, 34 Cong., 3 Sess. See also Marsh, p. 210.

he could not rise; Wayne then put two more bales on, making 1,256 pounds in all. The camel rose easily and walked off. Wayne wrote to Davis that it quite convinced the skeptical and that it caused a Texan poet to break into verse in the *Indianola Bulletin.* Later Miss Mary A. Shirkey, of Victoria, Texas, knitted from camel's hair a pair of socks for President Pierce. Major Wayne forwarded them through the secretary of war.[11]

During the latter part of May the camels were marched by easy stages to San Antonio where they were kept nearly a month and then removed to Val Verde (Green Valley)—a military post sixty miles southwest of San Antonio. Here at Camp Verde, as it was called, the permanent camel post was located. In September Wayne sent camels and horses to San Antonio for supplies. The camels easily brought 600 pounds each; six of them carrying as much as twelve horses could haul in wagons and in forty-two hours less time; the camels made the sixty miles in two days and six hours, while the horses required over four days. Later tests, made in November and December, 1856, showed that camels could easily climb mountain trails where wagons could not go, and that on muddy roads over which horses could not draw wagons, the camels traveled without fatigue. Only on slippery slopes were they troubled, and at the crossing of streams. Not being accustomed to fording, they had to be driven in by throwing water in their faces. At the end of 1856 Davis reported that in his opinion the experiment was a success.[12]

Davis left the War Department in March, 1857, and was succeeded by John B. Floyd. Wayne was transferred to Washington and the camels were left under the supervision of Captain J. N. Palmer, at Campe Verde. In 1858 the " Société imperiale Zoologique d'acclimatation " of Paris, awarded to Major Wayne a first class gold medal for the successful introduction and acclimation of the camel in the United States. Secretary Floyd was convinced of the usefulness of camels on the western plains, and in his second report, December, 1858, he recommended that 1,000 be purchased. This recommendation was repeated in 1859 and in 1860, but Congress paid no attention to the matter.[13]

After 1857 some of the camels were sent to the army posts at El Paso and Bowie. They were disliked by the army hostlers; the Arabian and Turkish caretakers were regarded with contempt, and it was difficult to get the American hostlers and wagon masters to help in the experiments. The horses objected to the smell of the camels when stabled or picketed near them and the hostlers sometimes turned the camels loose to get rid of them. However, during the four years before

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[11] Sen. Ex. Doc., No. 62, 34 Cong., 3 Sess., p. 148–63. *Harper's Magazine,* October, 1857.

[12] Sen. Ex. Doc., No. 5, 34 Cong., 3 Sess., p. 22.

[13] Sen. Ex. Doc., No. 2, 36 Cong., 1 Sess.

the outbreak of the civil war some interesting and successful attempts were made to use the "ship of the desert" for military transportation purposes. The first lengthy expedition was made by Lieutenant Edward F. Beale, who on September 1 set out to make a wagon road from Fort Defiance, New Mexico, to California. Camels, as well as mules, were used by the road-making party. The work lasted forty-eight days. Beale reported that the camels had been subjected to the severest tests and had failed in no instance; that they even learned to swim rivers. Beale considered that one of them was worth four good mules. From 1857 to 1861 Beale with twenty camels was occupied in exploring the unknown regions of the southwest. He found that the camels could do successfully all that was required of them. By 1861 his herd of twenty had increased to twenty-eight.[14]

Other trials of the camels were made in 1859 by Major D. H. Vinton, who used twenty-four of them in carrying burdens for a surveying party.[15] From May to August, 1859, Lieutenant Edward L. Hartz was in charge of the camel herd. Hartz sent to the War Department a full journal of an exploring expedition in which camels and mules were used. His verdict was not quite so enthusiastic as those of Wayne and Beale, but he pronounced the experiment a success. The camels were inferior to mules, he said, on slippery surfaces; they were not as good climbers as mules, but they were much swifter on level, rocky or sandy ground; it was difficult to keep the loads on the camels and frequent stops had to be made to replace the saddles, which could not be properly fastened by inexperienced packers. It was his belief that the female camel was better than the male; that the camels really preferred bushes, dry shrubs and grasses to grazing grasses; that they could go without water for more than two days and not suffer. All in all, he concluded, the camel was much superior to the mule.[16]

The success of the War Department tests caused other importations. In 1858 a British vessel brought over two cargoes of camels for a Mrs. Watson, who lived near Houston, Texas. Arab caretakers were employed and F. R. Lubbock, later governor of Texas, was put in charge of them. He says that they were healthy, and useful, but that they created too much sensation when they went into Houston or traveled about the country.[17]

There is a tradition that ten animals were brought to New York in 1857; of these two survived and were sent to Nevada, where by 1875 their offspring numbered ninety-five.[18]

In 1861 a San Francisco company imported twenty Bactrians (two-

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[14] Circular No. 53, Bureau of Animal Industry, 1903.

[15] Sen. Ex. Doc., No. 2, 36 Cong., 1 Sess., p. 422.

[16] Sen. Ex. Doc., No. 2, 36 Cong., 1 Sess., pp. 425–41.

[17] Lubbock, "Six Decades in Texas," 1900, p. 238.

[18] Leonard, pp. 14, 123.

humped) camels from the highlands of Asia for use in transporting salt from Esmeralda County, Nevada, to the Washoe Silver Mill, a distance of two hundred miles. The discovery of a nearer supply of salt left the camels without regular occupation. Some were used near Virginia City as late as 1876 to carry cord-wood.[19]

When the civil war began the government camels were scattered. Some were at Camp Verde, Lieutenant Beale's herd of twenty-eight was in California, and others at various posts in Texas. Beale, whom in 1861 Lincoln had appointed surveyor-general of California, proposed to Stanton that the government animals, which were scattered about in California doing nothing, should be turned over to him for use in carrying supplies and in making explorations. His request was not granted. In 1863 an attempt was made to use the camels in carrying the mails between New Mexico and California, but the officers in charge of the mails, knowing nothing of camels, objected and they were not used. In 1864 the herd, now numbering thirty-five, was sold to Samuel McLaughlin, who disposed of them later to circuses and zoological gardens.[20]

The herds at Camp Verde and other places in Texas were constantly used by the army quartermasters up to 1861. The ugly animals were well known sights in the towns near Camp Verde and between San Antonio and the gulf coast. But horses were often frightened by them and people began to regard them as a nuisance; Brownsville had an ordinance forbidding them on the streets. When the United States forces were withdrawn from Texas in 1861, the camels fell into the hands of the Confederates who made little use of them and spent little care upon them. They were turned loose to graze and some wandered away. Three of them were caught in Arkansas by union forces and in 1863 they were sold in Iowa at auction. Others found their way into Mexico. A few were used by the Confederate Post Office Department. At the close of the civil war the animals at the Camp Verde station, numbering sixty-six, were advertised for sale. Only three bids were received, one for $5 each, one for $10 each, and one for $31 each. So on March 8, 1866, the quartermaster in New Orleans sold to Colonel Bethel Coopwood the camels then in Texas. Colonel Coopwood carried them to Mexico and disposed of them to traveling circuses.

The stray camels were heard from occasionally—stampeding horses and ravaging fields. The Indians killed and ate some. The Navajos, it is said, once tied a Mexican shepherd to a camel's back and turned the animal loose. During the seventies soldiers in the southwest reported seeing strange camels.[21] Colonel Philip Reade writes that in July, 1875, he saw a herd of wild camels near Oatman's Flat, on the

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[19] Circular No. 53, Bureau of Animal Industry.

[20] Circular No. 53, Bureau of Animal Industry.

[21] *Taylor-Trotwood Magazine*, June, 1907.

Gila River. One of the government camels was living a few years ago in the public parks of the City of Mexico.

The attempt to make use of camels might have succeeded under different conditions. Davis, the strongest advocate of the use of the camel, went out of the war office just as the experiment promised success. Major Wayne, who alone of army officers had full theoretical and practical knowledge of camels, was transferred to office work at Washington, and Beale, who later accumulated considerable experience, was not encouraged by the War Department officials. The army teamsters and most of the officers outside of the Quartermaster's Department, took no interest in the matter and some opposed the experiment; the members of Congress were too deeply engaged in sectional controversies to care much about transportation problems in New Mexico. The Civil War afterward occupied the attention of those in authority while the herds were neglected, and the fact that Jefferson Davis had inaugurated the experiment was, in the opinion of many, enough to condemn it. After the war the rapid development of railroads solved many of the problems that seemed so serious in the fifties.

And yet had Wayne, Beale and Hartz been given ten years of favorable conditions, it is probable that camels would now be used as beasts of burden in some parts of the south and west, for conditions still exist in that section under which the camel would be useful.

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RAILROADS AND THE SMOKE NUISANCE

By CLINTON ROGERS WOODRUFF
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IT is estimated, so says the *Scientific American,* that 150,000,000 tons of coal are used annually by the railways of the United States, out of which but 7,500,000 tons are used in drawing the trains, while 142,500,000 tons go up the smoke-stack. And a recent English writer, John W. Graham, declares that a locomotive uses 3½ tons of coal per day on an average, and scatters the smoke of 36 pounds of coal over every mile on fast trains.

These two statements give us some conception of the appalling extent of the smoke nuisance so far as the railroads are concerned, and fill us with amazement and incredulity. How is it possible that railroads which are run for the profit of the stockholders, or at least are presumably so run if we may credit the statements made before legislative committees by their representatives, can permit so great a source of waste to have gone so long unchecked? Why is it that so many railroad officials have opposed in every way possible efforts to reduce the evil?

In Boston, according to one observer who has carefully studied the situation, the New York Central and Hudson River Railroad Company, through its officials, curtly refuses to discuss the matter or to make any change in its smoke-producing methods, and he made substantially the same charge against the New York, New Haven and Hartford road. Z. A. Willard in an open letter to the Boston *Herald* (on March 7 last) declared that

> Having been deeply interested for many months past in an endeavor to prevent or mitigate the smoke nuisance resulting from the use of soft coal on locomotives engaged in suburban traffic, I was called in consultation by the Boston management of the New York Central and Hudson River Railroad and informed that under no circumstances would this company make any change involving expense. Economy was now the ruling consideration.
>
> When informed that the nuisance could be entirely obviated by the use of coke—coke being no more expensive than soft coal—the answer was the same, "Economy."
>
> When reminded that eighteen locomotives had been constructed for the suburban traffic designed especially for burning anthracite, the answer was the same, "Anthracite costs money, and would not be considered." So that if so small a matter as the prevention of annoying smoke will not be considered by the New York Central authorities, tunnels, electricity, etc., may as well be relegated to the limbo of the impossible.

A correspondent of the Providence *Tribune* registered strong protest, as late as April 26, against the nuisance which the New York and New Haven Railroad Company is maintaining in the Elmwood district of the city. All day long the section is shrouded in a pall of dense, evil-smelling smoke and cinders, vomited forth by locomotives. The chief offenders are the short suburban trains, the expresses and heavy freights not causing half the bother made by the little fellows.

In and around New York City the aid of the Public Utility Commission had to be invoked to abate the nuisances maintained by these two roads in the matter of smoke. The New York Central in January last was ordered, "directed and required to cease and desist from the use of soft coal on any of the engines used by it on its New York and Putnam Division while within the corporate limits of the city and to institute and continue the use of hard coal on its engines."

The New York, New Haven and Hartford road was "directed and required to cease and desist from suffering or permitting in any manner the emission of black smoke from the stacks of the engines in use on the company's lines" while in the Harlem River Terminal Yard, and moreover it was ordered to cover all soft coal fires in engines with coke and to continually feed and replenish them with coke while the engines are in the yard.

Here we have the striking spectacle of two railroads being compelled by law to do certain things (and doing them, too) at one terminus, which they declare at the other end they can not do on the score of economy. At the one end (New York) there is a strong and effective law designed to protect the interests of the public; at the other, there is no such law, for, alas! the Massachusetts Railroad Commission, admirable though it is in many respects, finds that it is powerless to suppress the smoke nuisance.

The most striking defense of the railroad smoke nuisance, however, comes from the president of the Erie Railroad, one Frank D. Underwood, who is on record in a letter to Monsignor Sheppard, of Jersey City, rector of the Roman Catholic Church of St. Michael, that

> *There is a good deal of nonsense about coal smoke being injurious.* There is no healthier class of people in the world than those employed about soft coal mines, and they are begrimed from head to foot the majority of their lives.
>
> Permit me to state that men occupying leading positions, such as yours, are expected to allay senseless clamor against corporations instead of adding fuel to it, and it is hoped we may have the influence of your valuable efforts in our direction rather than adversely. Many of the people who gain a livelihood through the Erie Railroad I have no doubt are parishioners of yours and you should be able to ascertain from them whether there is more black smoke than is absolutely necessary in the operation of a railroad.
>
> In conclusion, the Erie Railroad was chartered fifty years ago, and it is identical with other interests in that it pays taxes. Is not something due to it, therefore? And was it not on the ground in advance of most of its complain-

ants? It is a penalty people pay for prosperity. The smoke-laden air of every city is but a testimonial of the general prosperity of the country. No smoke and rural stagnation is the rule—pleasant to live in, but not conducive to general prosperity.

All of which is respectfully submitted by the president in behalf of the board of directors.

Here then we have what we may appropriately call the official defense of black smoke! It is healthy; it is inevitable; it is a concomitant of prosperity and those who make it pay taxes! Surely a formidable argument, hardly requiring, however, a reply from the reverend Monsignor. Still parts of his reply are so apt as to justify quoting. After declaring that he had not asserted that the Erie engines could be run without smoke while consuming coal, he declared that the use of bituminous coal should not be tolerated in our cities, as it is not tolerated in New York, which had its

smoke problem and solved it as New Jersey should do; of course I need not tell you that the elevated roads running through the great arteries of the metropolis, and the Grand Central were to my mind a species of "railroad traffic" and therefore my comparison is not odious.

I have not said that any, or all, railroads are a nuisance, on the contrary, I consider them one of the greatest blessings, but I do most persistently assert that they are capable of committing nuisances, and in this particular instance under discussion are now injuring, as they always do, where such abuses are patiently borne, our property, and our homes.

I believe railroads do pay taxes. I do not know a great deal about this question, never having given it much consideration, but I do read occasionally that the whole machinery of the city and state have to be put in motion to collect the taxes levied.

From what you say of the healthy condition of the bituminous coal fields, which is not relevant to the issue, the attention of our leading physicians should be called to it. As health resorts these fields might enter into competition with the seashore and the Adirondacks.

No evidence is needed in any city of considerable size as to the existence of the smoke nuisance and of the part which the railroads play in maintaining it. There is an abundance of it on every hand; all too obvious, all too persistent. The encouraging feature of the situation, however, is the existence of a wide-spread and intelligent effort on the part of alert and progressive railroad officials to meet the situation and abate the nuisance. Largely, no doubt, because of the financial considerations, but in some instances because of a growing conviction that it behooves them to give heed to legitimate public demands, and because they are awakening to the fact that it is the wisest policy.

The recent orders of the Pennsylvania Railroad to its engineers and firemen may be said to be almost epoch-making in their importance and significance. This great corporation, in order to secure greater economy in the use of coal and to reduce the smoke nuisance, has inaugurated a special campaign of education among its engineers and firemen. A general order has been issued to the effect that "smoke means waste and must be avoided."

Five assistant road foremen of engines are now at work instructing firemen how to reduce the quantity of smoke emitted by engines. It is estimated that ten pounds of coal were required last year to generate steam necessary to haul one freight car one mile. The safety valve of an engine, if left open one minute, will lose an equal amount of steam. The Pennsylvania Railroad last year hauled 1,248,300 freight cars one mile and its coal bill was $10,000,000. Therefore, the savings of one per cent. by more efficient handling of coal will result in a saving to the company of $100,000 annually.

Under eighteen separate heads, thorough and minute instructions in the general order issued, the company has gone into the elementals of locomotive firing. Coal no larger than three inches thick may be used; tenders must not be overloaded so that coal is dropped along the track; grates and ash pans must be watched closely, in order to decrease the number of repairs on engines.

The example thus set by the Pennsylvania Railroad is bound to be of far reaching influence. As the Chicago *Record Herald* puts the case

> The argument should appeal to every smoke producer, for it would seem now that it had time to penetrate the smokiest kind of a brain. At any rate, its soundness has been demonstrated beyond question many times, and examples such as that of this great railroad corporation should add greatly to its force. But it is curious how long it has taken to convince smokers that the smoke actually meant waste, and how stubborn some of them are still in spite of all the teaching by precept and example. Conditions prove that they would never learn except under compulsion, under the determined attempts of the public authorities to abate a nuisance and to protect the thousands against the stupid selfishness and indifference of the law.

Another view of the attitude of the corporation was taken at the Providence meeting of the American Civic Association by the superintendent of motive power on the New York, New Haven and Hartford Railroad, Mr. George W. Welden, declaring that

> As a general proposition, railroad companies are assumed, by the rank and file, to take only such interest in the question of smoke elimination on locomotives as they are actually compelled to through the clamor of the public and the penalties imposed or prescribed by ordinances and enforced by the courts. If the above assumption were really true, then railroad operation in general could be properly classed as the most miserably managed business in the world. The New York, New Haven and Hartford Railroad, while constituting but a small percentage of the railroad mileage of the United States, and necessarily consuming but a small proportion of the total fuel burned on all railroads, could save annually for its treasury approximately $600,000 if some good Samaritan would suggest a method or device by means of which the black smoke and unconsumed gases which now escape from the smoke stacks of our locomotives could be completely burned and used as effective fuel. Second to

> the above-mentioned saving would be that accruing to the treasury because of the absence of the necessity of defending damage cases before the courts, involving, as they do, hundreds of thousands of dollars, and, naturally, the saving of the very large sums paid annually in fines. In addition to this, many incidental savings would be made in the form of less labor and time required to clean all classes of equipment both inside and out, including an increased life for the varnish on all classes of equipment. Coupled with this would be a decidely improved appearance.

Whether moved to do so by force of public opinion, by lawsuits, by economic considerations, or by the strong arm of the law as in the New York cases already cited, the railroads of the country are moving in the matter and moving in the right direction at a fairly rapid degree of progress.

The American Master Mechanics, in their latest session at Atlantic City, have declared that it is possible to stop the nuisance. Expert firing and proper stoking are the most efficient means. These master mechanics, who are mostly connected with the railroads, are of the opinion that smoke-consuming devices are of assistance in keeping down the flow of black soot that has resulted in the passage of city and state laws against use of cheap, soft coal as fuel, but the firing is of so much more importance in the work that recommendations will be made to sacrifice cost of expensive devices of the kind in favor of higher paid and more expert firemen.

This opinion is unquestionably shared by the Pennsylvania Railroad, for their most recent instructions are in harmony with this principle, and when their Cincinnati superintendent was asked if the company's firemen were arrested for violations of the local ordinances would the companies pay the fine, he said:

> No. The men would have to pay that themselves. We favor your getting after the men. We have suspended some firemen for making too much smoke. If they throw one shovelful of coal into the furnace at a time and do it frequently, they will not cause so much smoke. But instead of doing that, they throw in ten shovelfuls, and then take a rest. We have pleaded in vain with many to stoke in the right manner. Perhaps better results could be obtained if the league's officers went after them rigidly and called them to time.

Another student of the subject (Z. A. Willard, of Boston) has also reached the decided conclusion that the fireman on the locomotive is largely responsible for the nuisance. The firing of any furnace, locomotive or stationary, although generally considered a perfectly simple matter, is, on the contrary, a science requiring the services of a conscientious and experienced fireman, an opinion which is supported by Mr. Angus Sinclair, president of the Society of Locomotive Engineers, who, in his book on locomotive firing, gives his experience with two firemen on the same locomotive, running the same distance, on two successive days. The first fireman, in one hour and fifty-five minutes, the time occupied in the run, used eight thousand pounds of soft coal, making steam with difficulty, and filling the atmosphere with smoke. The next day, another fireman, with the same engine, running the same distance, used forty-five hundred pounds of the same coal, with plenty of steam and no smoke. The result was a saving of 43¾ per cent. of coal, and no annoyance from smoke. As the first condition is pretty nearly universal on roads where soft coal is used, the loss to the roads from ignorance or carelessness must be enormous.

Electrification is another method by which the smoke nuisance is to be abated.

On and after July 1 there are to be no more steam trains run into the Grand Central Station in New York. Electrification of the New York Central terminal, according to the New York papers, has progressed far enough to make this change practicable, and the order to run only electric trains into the big depot went into effect on July 1. This move does away with the nuisance of smoke, steam and gas in the Park Avenue tunnel. The new order applies also to the New Haven Railroad trains.

The Scientific American quotes some statistics from a paper read by W. S. Murray at a recent meeting of the American Institute of Electrical Engineers, which confirm and strengthen the testimony furnished by W. J. Wilgus to the American Society of Civil Engineers. They clearly show that electrification pays when tried.

In Mr. Murray's paper it is shown that to haul the express, local and freight trains of the New York division of the New Haven railroad now involves the consumption of 57,000, 58,000 and 188,000 tons of coal, respectively, whereas when the whole division is operated electrically the amount of coal burned for the respective classes of service will be 30,000, 28,000 and 139,000 tons.

In like manner the figures of cost and repairs of twenty steam freight and passenger locomotives on the New Haven road are given. They show an expense of 8.1 cents per locomotive mile for freight engines and 5.6 cents for passenger ones. The total mileage of the locomotives per year is easily ascertained and therefore the total expense for maintenance and repairs of locomotive service. The figures are placed at $316,962 per annum. Available figures for electric locomotive repairs show two cents per locomotive mile. Counting the same number of miles and the same number of engines, the total expense would show a saving of $196,038 per annum.

In brief, experimentation in the east has proved that electrification pays both in a great saving in the cost of the coal used and in the cost of maintenance and repairs. If it pays in the neighborhood of New York it will pay, as the Chicago *Tribune* maintains, in Chicago. It is electrification, not improved smoke consuming devices, that Chicago wants the railroads to experiment with. The head of the Illinois Central, however, J. T. Harahan, seems to think otherwise and in a long letter urges first that the art of electrification is in its infancy, and, secondly, that the experiments in the east have developed many difficulties.

Possibly if Illinois had a public utilities commission, like that of New York, President Harahan might take a somewhat different view of the situation, one more like that of the New York Central, although the economic argument ought to appeal to President Harahan and he ought not to allow the Pennsylvania Railroad to outdo him in the race for dividends or compliance with reasonable public demands. As one commentator on his position put it, "The financial question has two sides to it. The cost of electrification will be heavy. The cost of the smoke and noise nuisance to the community is a hundred fold heavier," and it could have pointed out that whatever makes for the prosperity and uplift of a community eventually makes for the benefit of the railroad.

According to Smoke Inspector Krause, of Cleveland, the smoke from railroads in that city has, within the past few years, been greatly reduced through the care that has been taken by the railroad officials. The inspector has one man who gives his entire time to this side of the work. Their records are sent to the offices of the officials and the crews are called in and reprimanded if the records show that they have been at fault. Some of the men have been discharged for not exercising proper care in this respect. The New York, New Haven and Hartford Railroad assumes a similar attitude. Recently it caused to be published this discipline bulletin:

> An engineman and fireman have been disciplined for permitting their engine to emit black smoke while standing in a passenger terminal some thirty minutes before leaving time, in violation of the rules of ordinary intelligence as well as those of the railroad company, and in disobedience of chapter 983 of the public laws of the state of Rhode Island,—J. A. Dodge, Superintendent.

Z. A. Willard, already several times quoted, declares as a result of his investigation that the use of coke will entirely eliminate the smoke evil, as it is free of smoke, soot and dust, and can be used on locomotives as at present constituted. The Boston and Maine Railroad is daily using seven hundred tons of Otto coke (produced by the gas works at Everett, Massachusetts) on all their short lines, and pronounces it perfectly satisfactory both to patrons of the road and residents along the lines, in avoiding smoke.

Some of the western roads use petroleum. For instance, the Mexican Central burns 4,000 barrels a day, at a cost of $1.10 a barrel. The Southern Pacific is also introducing oil-burning engines, especially for the switch engines. Hard coal is also used on the roads, which have convenient access to the anthracite regions, like the Lackawanna and the Reading; but other companies maintain that the cost of the coal and of changing their boilers prohibits the introduction of anthracite.

There is always some reason for not doing the obviously proper thing!

It is to be hoped, however, that the despatch of June 17 from Chicago is well founded. It reads to the effect that

> The general managers of railroads centering in Chicago claim that a determined campaign has been begun to secure greater economy in the use of coal, and at the same time reduce the smoke nuisance. Perhaps the most virtuous exponent of fuel economy is the Pennsylvania, the management of which has just started a campaign of education among its firemen.

To sum up: The elimination of the smoke nuisance, so far as the railroads are concerned, is feasible. Primarily it is a matter of proper firing and the use of the right sort of materials. The railroad officials are considering the question from various standpoints; some with a sincere desire to do all that possibly can be done as quickly as possible; others as rapidly as they are forced to do it by the law and by a militant public opinion; and a rear guard of hold-backs who are still closing their eyes to the obviously inevitable. These men will some day be disagreeably awakened, for the public is awakening on the subject and it expects everybody else to be.

ACCOUNT OF A TRIP IN SOUTHERNMOST JAPAN, WITH EARLY RECORDS OF ITS DISCOVERY

By Dr. ROBERT VAN VLECK ANDERSON
WASHINGTON, D. C.

ON one of the early days of May, 1905, three of us—a Japanese friend, my brother and I—were trudging through long avenues of pine trees and crossing the upland border line between the provinces of Hiuga and Osumi in southern Kiushiu and southern Japan. Kiushiu, the farthest south of the four main islands of Japan, is an exceptionally interesting and picturesque country, and perhaps the finest member of the archipelago. At this time we were traversing it diagonally from the open shore of the Pacific Ocean on the east to the bay and city of Kagoshima that mark the island's southern extremity. This is far from the center of the empire and the region of foreign traffic, and as yet there was no railway leading thither. The country paths are seldom trodden by foreigners, and the towns and villages are rarely afforded the amusement of a stranger's advent.

The rain was continuous, at times bringing such a downpour that it seemed to bid fair to flatten every object in the landscape. One who lives much out-of-doors in Japan must be reconciled to the coming of rain at all times, so we walked on gayly through it all, until the end of each day brought us to some inn where the night could be spent. As we neared our destination, the way followed torrents muddy with a burden of silt derived from the hills of volcanic ash and other volcanic rocks around about, and among green unterraced hills that reminded us of the limitless smooth slopes of home in America, so unlike were they to the usual terraced, stone-walled and rice-grown hills with forested tops that one knows throughout Japan. Finally we crossed over the axis of the island, the main divide, whence precipitous volcanic slopes led down through the rain-mist to the bay and islands that we could not see. Neither could we see the great smoking volcano Kirishima-yama, of which days before we had caught a glimpse from far in the north in the vicinity of Aso-san, and which we were later to view from southward on finer days.

After descending from the mountains and skirting the bay through extended ill-smelling fishing villages populous with staring people, we reached Kagoshima, the city of gardens and rich semi-tropical growth, the great port of the south. Here one looks down from one's balcony upon whole streets of shipping agencies, where hang great black and white placards of Chinese characters advertising dates of departure that are never kept. Here there is a beauty in the landscape and a spirit of liveliness in the people that invites one to stay, and an invitation in the bay and boats to go adventuring southward to the little-known Liu Kiu Islands and Formosa, from relations with which this most charming of Japanese cities acquires much of its character. And here one is in the heart of the old province of Satsuma, famed for its porcelain of centuries, and its heroes, and its influence on the history of the empire from the earliest day to the very present.

During most of our stay a warm rain was flooding down over the city, interfering with the manufacture of "ancient" Satsuma ware, and hindering the departure of all steamers, which seldom go when it rains and thus give their crews and passengers the enjoyment of furloughs much of the time. It was entertaining to sit in kimono on the balcony outside of the paper windows and look down on the scene in the streets, at the constant flow of people walking with bare feet and bare legs along the muddy ways under brown oil-paper umbrellas; at the shoulder-borne baskets heaped with yellow "biwa," or loquats, with chrysanthemums and lilies; at the wide bamboo rain hats from under which rang out the musical cries and songs of men and women, basket carriers, venders of fish just out of the water, turnips just out of the ground, young bamboo sprouts that have grown over night and will be eaten for dinner, fruits, cakes and flowers to decorate the shrines.

A few days more brought out the sun and the full plant life of the height of spring, and all the clearness of outline and symmetry of the island-volcano Sakura-jima, which springs from a bay rivaling that of Naples in the loveliness of its water and surroundings. And it was rather to my disappointment that, with the coming of good weather, the little boat which we had been waiting to take to the islands farther south finally made up its mind to leave for Tanegashima.

This island lies south of Japan in latitude 30° 30′, and is separated from Kiushiu by the Van Diemen Strait. It is long and low and narrow, trending northeast, its length being thirty-six miles and greatest width seven. It is composed of highly tilted strata of Tertiary age. Its people are Japanese, and as far as known it has always belonged to Japan, being in every way more closely related to that country than to the more southern or Liu Kiu islands that form a long curving chain down to Formosa.

Tanegashima was the first portion of Japan to be discovered by Europeans centuries ago, and it was here that the Japanese first became acquainted with members of that other race. With the foreigners came a knowledge of firearms, which spread from this island to the rest of the empire. For this reason Tanegashima was the name formerly applied to all firearms, and to the present day some pistols are still so called.

To-day the island is not greatly changed from its condition at the time when the first Europeans came to its coast. Few foreigners have been there since, and on going there one in a measure reexperiences the impressions that must have come to those early navigators, and presents a somewhat similar appearance to the present inhabitants as did those first foreigners to the earlier generation. The people live in a world of their own, and are connected with the mainland—a mainland that is itself an island—merely by a little one-hundred-ton steamer that runs with a reliable lack of regularity.

The sixty-mile ride out to sea from Kagoshima on this steamer was to be an all-night one. We purchased the best accommodations to be had and were off down the bay in the evening. The process on boarding a boat in Japan, after taking a sampan or scow out from the landing to where the boat is moored, is first to see to the safe storage of one's heavy baggage, and then, taking off one's shoes, and bowing the head, to enter the little door of the cabin that serves as sitting-room, dining and bedroom for those of the class to which one's ticket entitles him. Bowing the head is in this case not an act of politeness but merely of practical utility in preserving one's cranium and temper, and a practise that a foreigner in Japan learns to remember after many daily lessons. After one has entered, the act of kneeling and bowing to the floor as a greeting to those already present is an act of politeness which though dispensable is always appreciated by the Japanese. In the present case the cabin measured twelve feet by seven, and five feet in height, and already five men were squatting on the floor with their personal baggage, preparing to make a night of it. Presently four more came in and that made us twelve, a good-size company for such a cubby hole. Each spread his blanket down in the little crevice that was left for him, and as he tired of the talk and of the smoking—one can imagine how much the volume of smoke poured forth by each of the Japanese, with the exception of our friend, added to the general comfort—each cuddled down, sardined himself in, and was lulled to sleep by the chunk, chunk of the machinery, the occasional tapping of some lingering smoker's pipe on the bronze brazier, and the cradling of the boat as it stood out into the rough, splashing waters of the strait.

Early morning brought us in view of the low, forested sky line of Tane gashima, and we were soon rowed ashore across the little bay of Akaogi, or Nishi-no-omote, where the port and largest village is marked by a group of huts along the coral-strewn beach. We left our belongings on the beach, and threading our way through the gathering crowd of men and boys, and women and girls with babies on their backs, who were flocking to see us, we went to a little inn to make arrangements for a stay.

The *yadoya,* or inn, is one of the most typical and interesting institutions of Japan. The traveler will find it wherever he may go, now pretentious and from the Japanese standpoint luxurious, now very humble or even dirty. As camping out is next to impossible in that country, we made great use of the *yadoya* throughout our journeying.

As one steps before the wide open doors of the reception room, or into the court, or the kitchen as the case may be, the host approaches and greets with a low bow, followed by the hostess and usually one or more of the maids, who, kneeling, bend to the floor. The salutations are returned, a word is exchanged perhaps about the rooms or the meal that is to be prepared, and the guest seats himself on the low porch or platform that surrounds the entrances, and removes his shoes or sandals, leaving them on the ground. If one wears the Japanese cloth shoe and straw sandal, as I did some of the time, the feet are always washed in a wooden basin of water brought by a maid, who comes clattering around the outside of the house on wooden clogs, to bring it, and sets it down before one on the ground. A little towel is brought too, unless one, as usual, has this most useful of articles about his person. Then the guest steps in, in stocking feet or barefoot, and, preceded by a servant passes through the open rooms, often between a double line of all the people of the household who are bowing to the floor. He enters the room allotted to him and there seats himself cross-legged on a cushion on the matted floor before a tiny charcoal fire in a brazier, and rests—at least pretends to rest if he is a foreigner—until disregard for ceremony gets the better of him and he adopts an easier position. Presently comes a demure or smiling little maid, with rosy cheeks and fancifully colored silk kimono, who kneels outside and slides open the paper door, enters, kneels and closes it, brings tea things to the center of the room, and kneeling pours out a wee cup of tea to the guest or each of the guests. This done she bends her forehead to the floor and patters out, opening and closing the door as before. If the guest is an honored one some dainty, such as bean jelly or cakes, or raw dough rolled in pink and green powder is brought with the tea. Then the guest steps out to the porch to wash, and as he dries his face he looks at the little cultured garden, or off to distant valley, or forest or mountain, or sea. Returning to his room, he is most of the time alone until the coming of the meal; or if it chances to be afternoon or evening, until the announcement comes that "the bath is ready." One is never entirely alone; access to the room is always free on several sides and host, or visitor, or servant, may come in at any time. One becomes used to this and learns to like it in most ways. There is nothing hidden. It makes life simple and informal and more natural. We found it a disadvantage sometimes when we had too many visitors whose curiosity got the better of them, but we always took it in good part, finding it amusing rather than annoying.

After the tea-drinking that morning at Tanegashima, I opened a panel at one side of our room and stepped out on the porch under the low roof. Just before me was the white beach and the water's edge, where two junks that looked for all the world like ancient Spanish galleons were moored; and I looked off beyond to the little rock-hemmed bay banded with green and purple water under the changing cloud shadows, and still farther to the distant pine-crowned sand dunes and headlands fringing the blue of the open sea. To a stranger, such a scene is overpowering with a sense of isolation in which there are mingled elements of loneliness and charm.

Upon the announcement that "go-hang," the meal, or literally, the "rice," was ready, we squatted on the floor and the maid laid before each of us a square tray of viands, and herself kneeled to serve the rice from the wooden firkin. Each tray bore four main dishes, one in each corner, and a cup in the center. There were three bowls, an empty one of porcelain for the main food—rice, another of lacquered wood containing a very thin soup, and the third a mingling of dried fish and seaweed, while the fourth corner was occupied by a plate holding a small baked fish entire. The central cup contained two square pieces of pickled turnip. The maid remained throughout the meal and filled the bowls with rice when they were passed. And, of course, we ate with chop-sticks, drinking the soup. This was a typical hotel meal, purely Japanese, even more elaborate than what one would expect at a private home of people of the middle class, and far better than anything one is served with when traveling in country places away from the seashore.

The island of Tane is not very thickly inhabited and the people are fairly well-to-do. They are half fisher-folk, and the rest farmers or peasants. The low hills that rise from the coast leaving no bordering flat-land are wide and level on the summit, and, in contrast to most of the hills in other parts of Japan, are wooded on their flanks and cultivated on the top. Rice, wheat, yellow mustard for oil, and sweet potatoes are the principal crops. The little fields and patches are usually hemmed in by shrubbery and trees, or often by rows of banana palms. The people live in homesteads that come nearer to being homes as we know them than most of the habitations in other parts of Japan. The low houses with steep thatched roofs are bosomed in gardens of luxuriantly growing vegetables, vines, shrubbery, palms and flowers, with a deep, rich background of old cryptomeria, pine, oak, camphor and banyan trees. It was a pleasure to walk through the rank forest away from the coast on a hot summery day, and there to come upon old settlements framed in the abundant greenery and other coloring of the woods.

One of these old homes situated on the hills above Nishi-no-omote, was a wide rambling bungalow of wood and paper, roofed with tile and surrounded by a garden of trees trimmed with fantastic artificiality, of flowers and wild growth. Here lived the present member of the ancient noble Tanegashima family that previously ruled the island. My brother called on him one day, and was cordially received, and from him we obtained accounts of the first coming of Europeans to Japan and of the introduction of firearms. It was the custom to keep a family record, and the contemporary account of this episode of the history of the island is most interesting. In addition to the account set down at the time in the family records a complete narrative of the events was written by a priest of the island named Monshi about 1606, or sixty-three years after they occurred, when, as he says, there were still living some old men, with hair as white as the Japanese crane, who remembered the arrival of the foreigners. This narrative he called "Teppoki," or "gun-record." In recent years a history of the Tanegashima family has been written in Japanese by Tokihito Nishimura, and these original accounts are included in it. During some long rainy days on the island our friend Kiyoshi Kanai translated the family records and the "Teppoki," and we studied out their meaning and interpreted them in English as well and as closely as we could. They were written in old-fashioned Japanese and many passages are obscure in meaning and difficult to render.

As the "Teppoki" tells the whole story well and as it incorporates the account given in the family records, I shall give our translation of it, leaving out the other, which would be largely duplication.

> There is an island called Tane, 44 miles from Gushu.[1] Our ancestors always lived there. People say that the reason why they call it Tane is that, though it is small, it is full of people and they are all well-to-do. As a seed planted grows and brings forth fruit without end, so multiplied and prospered the dwellers on this island.[2]
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> On the 25th day of August, 1544, a large ship was found on the beach of Nishi-no-mura, and they did not know from what country it came. The whole crew numbered more than a hundred, the shape of their bodies was not like ours and they could not talk with us. The people that saw them thought them very curious. Among them there was a Chinese student named Goho; we had no way now of knowing his last name. The head officer of Nishi-no-mura was Oribenosho Tokitsura, and he knew a good deal. He met Goho and with his cane he wrote on the sand as follows:[3a] "We do not know whence the crew of the ship comes. How different their figure is!" Then Goho wrote: "They are merchants of the southwest barbarians. Though they know about the principle of emperor and subjects they are ignorant about ceremony. So that when they

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[1] The southern province of Kiushiu, now called Osumi.

[2] Tanegashima means literally "Island of seed," from *Tane*—seed, *ga*—of, *shima*—island.

[3a] The meaning of the written characters in Chinese and Japanese is much the same whereas the spoken languages are mutually incomprehensible.

drink they use a large dish, not the cup.[3] When they eat they use their hands and not the *hasu*.[4] They know only to do what their desire tells them, and have no knowledge of literature.[5] They are so-called merchants who travel to places and stay there. They only exchange what they have for what they want and are not men to be suspected."

Then Oribenosho wrote again: "Thirty miles from here there is a port called Akaogi[6] where the owner of the island always stays, where there are several thousand houses and every house is rich and the streets are crowded. If we lay anchor there, there will be no danger, for the harbor is deep and the water smooth." And he sent word to Etoki and Tokiaki.[7]

Now the ship was conveyed by several tens of small fishing boats, and it entered Akaogi on the 27th.

At that time there was a priest named Chushuza, who had come from the Riugen temple of Hiuga and was staying at the port to learn about the Hokke sect, and who finally changed over to be a priest of the Hokke sect from that of Zen, and was called Diuzoin. He knew the sacred books and could write skilfully, and he could speak with Goho. Thus Goho found a friend in this foreign country and felt, as it is said, that there was "one voice, one heart" between them.

There were three head merchants; one was Murashusha and another was Kirishita Demoto.

They had an article in their hands that was about two or three feet long. There was a hole inside of it, and outside it was straight. It was made of very heavy materials. Though there was an empty passage on the inside, this was tightly closed at the end. There was a hole in one side to pass fire through. We could find nothing to compare with its shape. When a man used it, he would put a wonderful medicine[8] into it, add a leaden ball and set up a white mark on the coast; and then he would hold it up, keeping one eye closed and the body straight, put fire through the hole and always hit. When it fires it looks like lightning and the sound is like the rolling of thunder. Every one who heard covered both ears. After marking a white spot on a rock a man could shoot at it very accurately. With the firing off of this thing silver mountains could be destroyed and iron walls dug through. Enemies who do harm to a man's country would be very much frightened on meeting this, and still better would it be for hunting the deer or boar that do injury to young plants. There were many ways of using this article. When Tokiaki saw

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[3] To the oriental, drinking tea or liquor is a significant ceremony and the little porcelain cup is a part of the form. The departure from this way and the use of a large coarse bowl or mug, such as from their standpoint should be used only to eat from, doubtless seemed an indication of barbaric crudity.

[4] What we call, with insufficient reverence, chop-sticks.

[5] "Literature" here connotes learning, culture, ceremonial. These commentaries are interesting; they illustrate another point of view. The bases of judgment are exactly similar to those applied to-day by many Europeans and Americans in passing judgment on the orientals.

[6] This is the chief port and town of the island, now most frequently called Nishi-no-omote. It is the port to which we came, as before stated.

[7] Etoki and Tokiaki were father and son in the ruling house of Tanegashima. The latter was at about this time succeeding his father in the position of responsibility.

[8] The present word for powder in Japanese means "fire medicine."

it he thought it was the most wonderful thing in the world. At first he did not know any name for it or how it was used, but it finally acquired the name "teppo." I do not know whether it was so named by the Chinese or by our island-people.

One day Tokiaki said to the barbarians through the interpreter: "I can not shoot this very well, I wish to learn." The barbarians answered, also by means of the interpreter: "If you wish to learn this we will go to the very bottom of it with you." Tokiaki said: "I would like to go to the deepest principle." The barbarian said: "All that is necessary is to quiet the mind and keep one eye closed." Tokiaki answered: "To adjust one's mind was taught by the old sacred teachers, and that is what I have learned. In general throughout the world if the mind is not under control all conduct will be false. What you say in regard to controlling the mind must mean just this. But about closing one eye—if it is not bright enough without both to put a candle at a distance,[9] is it necessary to close one eye?" The barbarian replied: "Well, everything must be done in a simple way."[10] Tokiaki said gladly: "That may be as Roshi said, 'To say clear, looking small thing.'"[11]

On a certain ceremonial day Tokiaki put a white spot at one hundred steps away, and with the wonderful medicine and a small lead ball he shot pretty closely. People were surprised, and when it hit they were frightened. He said solemnly: "I wish to learn." Tokiaki did not complain about the fearfully high price, but bought two teppo from the barbarians and added them to the house curios. He had the small vassal Sasagawa Koshiro learn the method of making the medicine. Tokiaki studied very earnestly; the first time he shot pretty closely; but later if he shot a hundred times he hit a hundred times, and never failed even once.

At that time a priest named Sugibo of Negoro temple in Kii[12] came to get a teppo, not caring for the distance. Tokiaki was affected by that strong desire for searching, and thought to himself: "In the olden time Jiokun coveted Kisatsu's sword, though he never let it be known by words. Kisatsu found it out and gave him his honorable sword. Our island is small and we can spare one teppo. I came by them unexpectedly and I was so overjoyed that I did not sleep, and had a strong desire to hand them down to my descendants. How much more delighted would a person be to get one after having searched for it. What I like, others will like. Why should I conceal them in boxes?" So he sent Tsuda Kanmotsunojo to Sugibo with one of them and let him know how to make the medicine and how to set it off.

As Tokiaki prized the firearms very highly he had several blacksmiths examine them, and desired them to make new ones. Though they got the shape almost the same they could not discover the way to close the end.[13]

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[9] This probably means, "If with only one eye I can not see any better than by candle light."

[10] Probably means, "It requires concentration."

[11] This probably means that clearness of statement is aided by considering one point at a time. There is a suggestion of similarity here to the passage in Matthew VI., 22, "if therefore thine eye be single, thy whole body shall be full of light."

[12] The Kii peninsula in central Japan, several hundred miles away.

[13] The difficulty that they encountered was probably in finding a way to close the stock end of the barrel, when once they had molded a barrel tube, open at both ends, around a smooth rod. They learned to do this later, probably by screwing in a breech plug and welding the end.

> The next year the foreign merchants came back to Kumano. . . . Fortunately there was a blacksmith among them. Tokiaki thought that to be a gift from heaven and ordered Kimbioe Kiyosada to learn the way to close the end. After awhile he learned how to do it by means of a screw. Thus in the course of a year they were able to make several tens, and after that they made the wooden parts and the other decorations.

This completes the main portion of the "Teppoki," but the family record of the smith Kimbioe Kiyosada which is also preserved forms an interesting addition. Here is a translation of part of this contemporaneous account:

> Kiyosada brought about the relation of teacher and pupil between one of the strangers and himself with the purpose of learning the way to make the teppo. He thought that the barbarian would never tell the truth and that it would be better to give his daughter to him and let him marry her. Though he learned how to shape the teppo he did not understand how to close the end. After several months the ship went away, with the daughter, and many presents were left.

The record goes on in more detail and tells us the outcome. The daughter was seventeen years old and her name was Wakasa. After a year's time the ship returned, as the other records tell also, and Kiyosada found out how to complete the making of the firearms. Wakasa returned to her parents, and the family in order to keep her pretended to the strangers that she was dead and that the burial ceremony had taken place. The family of Kiyosada still lives on Tanegashima and is in possession of some porcelain ware presented at the time by the merchants.

The foregoing narrative is a history of the discovery of Japan by Europeans from the standpoint of the Japanese themselves. It is interesting to compare with this the story as written by one of the discoverers. The Portuguese navigator, Ferdinand Mendez Pinto, after returning home, described his many experiences in his book "Peregrinaçaõ," and among them, his arrival at the island Tanegashima, or, as he called it, *Tanixumaa.*

He set out from Cochin China for a journey in the China seas, and after various wanderings through the Liu Kiu islands and elsewhere came by chance upon Tanegashima. This was the first time that any portion of Japan had been seen by Europeans. He was accompanied at this time by two other Portuguese, *Diego Zeimoto* and *Christovano Borralho.*[14] Later he went to other parts of Japan farther north. The

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[14] The names in the Japanese account were *Murashusha* and *Kirishita Demoto.* As one Japanese writer says, foreign names are to their people "like cold water to the sleeping ear." The names must have been ill understood and imperfectly represented in the Japanese syllables and there may have been a still further departure from the original in the present retranslation. The former may stand for *Mendez Pinto.* The first name of the second doubtless stands for *Christovano* (*Bolero*), (the Japanese now say *Kirish* for *Christ*),

whole story is most interesting, but there is place for only a few extracts here. Their junk hove to first at the southern end of the island and was then conducted by native boats to "a great town, named Miaygimaa"[15] where the chief nobleman of the island soon came on board. The account reads:[16]

> He no sooner perceived us three *Portugals*, but he demanded what people we were, saying, that by our beards and faces we could not be *Chineses*. . . . Thereupon having called a woman of *Lequia*,[17] whom he had brought to serve as an interpreter between him and the *Chinese*, captain[18] of the junck; "*Ask the Necoda,* said he unto her, *where he met with these men, and upon what occasion he had brought them hither with him into our country of Jappan?*" The captain thereunto replied, that we were honest men and merchants. . . . After he had seen all the commodities in the junck, he sate him down in a chair upon the deck, and began to question us about certain things which he desired to know, to the which we answered him in such sort, as we thought would be most agreeable to his humour, so that he seemed exceedingly satisfied therewith; in this manner he entertained us a good while together, making it apparent by his demands that he was a man very curious, and much inclined to hear novelties and rare things.

On leaving the vessel the lord of the island asked the strangers to come ashore and visit him, and they did so, being royally entertained and answering many questions regarding the world from which they had come, which was entirely unknown to the Japanese. Within three days all the goods on the ship were disposed of at great profit, but Pinto and his companions remained on the island after that more than five months. Again the narrative reads:

> Now as for us three *Portugals*, having nothing to sell, we imployed our time either in fishing, hunting or seeing the temples of these *Gentiles*, which were very sumptuous and rich, whereinto the *Bonzes*, who are their priests, received us very courteously, for indeed it is the custom of those of *Jappan* to be exceedingly kind and courteous. . . . *Diego Zeimoto* went many times a shooting for his pleasure in an harquebuse that he had, wherein he was very expert, so that going one day by chance to a certain marsh, where there was a great store of fowl, he killed at that time about six and twenty wild ducks. In the mean time these people beholding this manner of shooting, which they had never seen before, were much amazed at it. . . . The lord of the island sent presently for *Zeimoto*, just as he was shooting in the marsh, but when he saw him come with his harquebuse on his shoulder, and two *Chineses* with him carrying the fowl, he was so mightily taken with the matter, as he could

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and the last name for *Zeimoto*, especially as the Japanese account says distinctly that there were three men.

[15] The name of the chief town which was then as now the chief one of the island, and to which Pinto came according to the Japanese account, is Akaogi or Nishi-no-omote. He evidently confused with it the name of the small island Mage-shima that lies a few miles out to sea in front of the town.

[16] From the translation by H. C. Gent published in London in 1663.

[17] Pinto's version of Liu Kiu, the name of the island chain to the south.

[18] The three Portuguese were then traveling in the vessel of a Chinese pirate.

> not sufficiently admire it; for whereas they had never seen any gun before in that country, they could not comprehend what it might be, so that for want of understanding the secret of the powder, they all concluded that of necessity it must be some sorcery.

The story goes on to tell how the nobleman took Zeimoto up behind him on his horse and had criers declare through the town that thereafter he considered him as his kinsman, and that he should be treated accordingly on pain of death. The lord treated Zeimoto very kindly, and the latter, according to Pinto, presented his harquebuse to the lord, who gave him in return 1,000 *tæls* silver.[19] The lord took more pleasure in shooting the gun than in anything else, and many of his subjects set to work to learn to make firearms. Pinto says that when he returned to Japan another time, which was in 1556, he was amazed to find how the art of making guns had spread, and he says that on expressing his amazement:

> "Certain merchants of good credit assured me that in the whole island of *Jappan* there were above 300,000 harquebuses. . . . So that by means of that one, which *Zeimoto* presented to the *Nautaquim* in acknowledgment of the honour and good offices that he had done him . . . the country was filled with such abundance of them, . . . whereby one may perceive what the inclination of this people is, and how much they are naturally addicted to the wars, wherein they take more delight than any other nation that we know.

The first finding of Japan by Europeans opened the way to the coming of more merchants, and missionaries. It was not long after that St. Francis Xavier came and converted large numbers of the Japanese to Christianity and started this new religion, which in later years gained such a firm rooting and developed among the Japanese some of the bravest Christian martyrs known to history. During following centuries a very important trade continued between Japan and the Portuguese, Spanish and Dutch until the country was opened to the world by America in 1854.

We found the people in many of the out-of-the-way parts of Japan not much altered, it would seem, from what they were centuries ago, and just as much filled with curiosity as they were then at the coming of "red-haired barbarians with green eyes." To cite just one instance —one day an old man who had never seen a foreigner before sat for half an hour outside our door, which happened to be a little open, and watched us while we were eating. I heard later that his comment was—"they have beautiful complexions but I do not like their hair." A light complexion is always considered an element of beauty, and for this reason a large proportion of the girls use powder, although their faces are in general whiter and rosier naturally than the men's. Black hair is, of course, an element of beauty, and sandy hair such as ours is not, since black is practically the only color known among themselves;

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[19] Compare this with the Japanese account of the transaction.

and as for blue eyes—if a Japanese, having never seen them, could imagine them at all it would only be with horror.

The people of Tanegashima are rather easy-going, and along the coast are often poor and dirty, rather from indolence than lack of opportunity. When not lounging idly they are at their fishing or sea-weed gathering, or the women in their sweet-potato patches. All down the rocky coast one sees ragged children playing, and naked men with well-formed bodies of the color of bronze, working at their boats and nets or swimming in the sea with baskets gathering edible sea-weed. In the fields, too, the peasants work almost naked during the warm days. The coast is one of rocks and pools and waves, of fish-nets spread out to dry, of dirty fishing shanties, of coral walls surrounding the yards, of salt-making paddies, and long reaches where nothing grows but grass and shrubs and pines.

Our wanderings took us along the coasts, across the island and down its center, and afforded us many experiences and views that are memorable. Toward the southern end we stayed one night at Kumano Bay on the eastern coast, the place to which the foreign ship of Mendez Pinto came first, and where lived the blacksmith Kiyosada who first learned to manufacture firearms. Here there is a large inlet among the hills that is filled with water only when the tide is in, where one sees "now horseback riders and now the white sails of boats" as one Japanese writer quaintly puts it. We walked across the dry, flat floor of the bay one evening on our way out to the seacoast to examine some caves. Returning after dark we started across it and found it full of water up to our waists. At every step we took, the disturbed bay gleamed with phosphorescence in a circle all about us and made a fine picture here in the valley of water between pine-crowned hills that stood out even blacker than the night. Here where the landscape changes with the tide is the holiest place in the island, and we had the pleasure of spending the night with the priest of the Shinto shrine in an exquisitely beautiful Japanese house that had just been built for him. He lived alone, but called in a charming lady and her perfect little daughter from the neighboring hamlet to prepare our food. The meals were very simple, but neatly and daintily served, after the general plan of the meal before described. The priest did not eat with us, but we sat with him and talked for some time by the open fire that was burning in a basin in the floor. The custom of having fires differs among the Japanese. Usually in the hotels and private houses there is a wood fire on the dirt floor or in a rough stove in the kitchen, and nothing but braziers in the living rooms. But often also, in the country homes especially, open fires burn in a round hearth in the center of the house. There is never a chimney, and in the present case the rich new wood-work of panel and ceiling was fast becoming blackened with smoke from the tarry pine wood.

We went to sleep on short mattresses on the floor, under covers of silk, and so passed one of the last of our nights in Tanegashima. Before leaving this southern end of the island the next day I climbed a high hill and saw the great blue mass of the island Yakushima that rises under a dense cover of old forests over six thousand feet out of the sea not far away. To this island I sailed a few days later, while my brother left me to go back to the north.

It was just at the time when the long expected Russian fleet was gradually crawling toward Japan, and the whole country, ignorant of the fleet's whereabouts and of the route that it might take, and not knowing at what moment it might strike, was calmly and confidently awaiting its arrival. On several different days we had heard occasional distant rumblings that did not sound at all like thunder and did not approach nearer. We thought to ourselves, could that be distant cannonading? But although the noise was probably due to distant thunder storms it added something of awe and doubt to the suspense. Finally the news came, and the intoxicating, unbelievable story of wholesale success was quietly received and at once believed by the people as if it were only what had been expected. A couple of days after the great victory, as I was sailing across the straits to Yaku Island, I saw a Japanese war vessel swooping down the coast of southern Kiushiu, probably in search of any Russian ship that might possibly have escaped. The war, now almost ended, which had been carried on with such assured skill by the Japanese, gave an added significance to the first introduction of firearms and a prophetic truth to the words of Mendez Pinto at the end of the passage quoted above, and to the following words with which the priest Monshi summed up his "Teppoki":

> After this, throughout the eight provinces, and even in the country districts, every one obtained guns and practised. . . . In the first place Tokiaki got two guns from the foreigners and learned their use. One shot shook all Japan.

AN AMERICAN CONTRIBUTION TO THE HISTORY OF THE PHYSIOLOGY OF DIGESTION

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MY interest has lately been aroused in reading a little American monograph published over a hundred years ago as a dissertation submitted for the degree of doctor of medicine to the faculty of the University of Pennsylvania. It is entitled: "An Experimental Inquiry into the Principles of Nutrition and the Digestive Processes," by John R. Young, of Maryland (submitted June 8, 1803).[1] The essay does not appear to have received notice from the writers of that period; nor was there, probably, more occasion for calling attention to this monograph than to the usual doctor's thesis of the present day. Dr. Young's contribution, nevertheless, seems noteworthy because, in examining the knowledge of digestion then current, he applies the test of experimental evidence obtained at first hand—a sort of critique less in vogue in his day than in ours. On the title page he quotes from Lavoisier: "We ought in every instance to submit our reasoning to the test of Experiment, and never to search for truth, but by the natural road of Experiment and Observation." The dissertation further possesses a value, aside from its intrinsic merit as a scientific inquiry, in giving some indication of the status of physiological studies in America at the opening of the nineteenth century and in the first medical college of this country. To appreciate Dr. Young's monograph in the light of those times one must indulge in a moment's retrospect.

The history of the physiology of digestion may conveniently be divided into three periods. The first of these embraces the earlier days of science until the publication of Haller's "Elementa Physiologiæ" (1757), when theory and debate still maintained the triumph of the "animal spirits" and the various conceptions of "vital principles." In the succeeding epoch Réaumur (1752), Stevens (1777) and Spallanzani (1783) put into practise the teaching of Bacon:

> Non fingendum aut excogitandum, sed
> quid natura faciat observandum.

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[1] I am indebted to Dr. C. F. Langworthy, of Washington, for directing my attention to this paper. It is reprinted in the Medical Theses, edited by Charles Caldwell, M.D., Philadelphia, Thomas and William Bradford, 1805, which was obtained for the Yale University Library through the courtesy of the Library of the Surgeon General's Office in Washington.

Previous to this time various theories of digestion were based upon obscure ideas of trituration, concoction, fermentation and putrefaction or whatever these words might imply. Difficult as it is for us to-day to reproduce the point of view of men who were "struggling with the spiritualistic fermentations of van Helmont, on the one hand, and with the material effervescences of Sylvius, on the other," we can nevertheless appreciate the remark of William Hunter:

> Some physiologists will have it, that the stomach is a mill, others, that it is a fermenting vat, others, again, that it is a stew-pan; but, in my view of the matter, it is neither a mill, a fermenting vat, nor a stew-pan; but a stomach, gentlemen, a stomach.

The third epoch in the study of the physiology of digestion coincides with the rise of modern chemistry and may, perhaps, be said to start with the discovery of free hydrochloric acid in the gastric juice by Prout and by Tiedemann and Gmelin in 1824, soon followed by the pioneer work of Dr. William Beaumont upon Alexis St. Martin. Foster writes:

> It was left for the nineteenth century to throw a new light on the nature of the gastric changes and at the same time shew that what took place in the stomach was not the whole of digestion, but only the first of a series of profound changes taking place along nearly the whole length of the alimentary canal.

Let us bear in mind, then, that although the presence of a solvent fluid in the stomach had begun to be admitted in 1803, its nature and the mode of its operation were not understood until Beaumont's classic experiments (1833) on "the man with a lid on his stomach," as St. Martin was derisively called. Réaumur (1752) experimented on a buzzard, administering to it hollow metallic capsules perforated like a sieve and containing foods within. The possibility of mechanical crushing or trituration was thereby excluded; but when the tubes were regurgitated it was found that digestion (solution) of the food materials had nevertheless taken place. Some chemical action must have been exerted; and by placing sponges in the metallic tubes, Réaumur was able to express therefrom specimens of gastric fluid. He appreciated that it possessed properties antagonistic to putrefaction; and fragmentary as his observations may appear, he introduced a new method into physiological research. To Spallanzani was left the extension of these investigations in most fruitful fields. He well recognized the antiseptic power of the gastric secretion. With regard to the nature of digestion Spallanzani concluded (1783) in these words:

> None of the three forms of fermentation distinguished by chemists under the name of spirituous (alcoholic), acid, or putrid, have any place in digestion.

His well-conceived experiments in which animals swallowed meat attached to strings by which it could be withdrawn from time to time, and the ways in which gastric fluid was removed by squeezing out sponges swallowed and withdrawn, are familiar. The impression which these researches left is well emphasized by Beumont. He wrote (1833):

> Suffice it to say that the theories of *Concoction*, *Putrefaction*, *Trituration*, *Fermentation* and *Maceration*, have been prostrated in the dust before the lights of science, and the deductions of experiment. It was reserved for Spallanzani to overthrow all these unfounded hypotheses, and to erect upon their ruins, a theory which will stand the test of scientific examination and experiment. He established a theory of CHEMICAL SOLUTION, and taught that chymification was owing to the solvent action of a fluid, secreted by the stomach, and operating as a true menstruum of alimentary substances. To this fluid he gave the name of GASTRIC JUICE. . . .
>
> By far the most respectable and intelligent physiologists have now settled down in the belief that chymification is effected in the stomach, by a specific solvent, secreted by that organ, called, after SPALLANZANI, the Gastric Juice. From the difficulty, however, of obtaining and submitting this fluid to the test of experiment, and the diversity of results in the examination of such as has been obtained, no very satisfactory conclusions have been arrived at. The presence of an active solvent is rather an admission—a conclusion from the effect to the cause.

Spallanzani failed to understand the acid character of solvent gastric juice. Even as late as 1825 Leuret and Lassaigne, in a memoir honored by the Académie des Sciences, declined to accept Prout's evidence of the existence of hydrochloric acid in the gastric secretion. This deserves notice with reference to the experiments of Dr. Young which will be described later.

Young's essay opens with a review of the Nutrientia, the views of Dr. Cullen being subjected to criticism. This famous Edinburgh teacher[2] referred "the principal of nutrientia to vegetables; and that they derive this property from their acid, sugar and oil." Taking these up in order, Young rejects acid as a true nutrient, with these words:

> The doctor (Cullen) appears to have founded his opinion on the idea, that all vegetable substances, when taken into the stomach, undergo a fermentation, whereby an acid is evolved; and "as this entirely disappears with the progress of the aliment, without being again evident in the mass of blood," so he supposed it undoubtedly entered into the composition of the animal fluid. That an acetous fermentation takes place in the human stomach in a healthy state, we entirely reject, as will appear in what follows; and if this opinion be well founded, we obviate the principal argument favouring the idea, of an acid being nutritious. Acescent vegetables we can not doubt as affording nourishment, but this is not to be referred to their acid, but to their sugar and oil.

Young overthrows Cullen's assumption that "sugar is not alimentary in its pure saline state, but only when combined with an oleaginous

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[2] I have assumed that the writer must refer to William Cullen (1712–90), of Edinburgh, under whose influence the abler young men from the English colonies in America came.

matter," by citing the case of the West Indies negroes who grow fat on sugar at certain seasons when they are at work on the cane. The absorption and need of water and "calcareous earth" is also discussed. The author reaches the conclusion that water not alone supplies the waste of fluids, but also goes to form the solids of the body. He says:

> Dr. Fordyce informs us he put a gold-fish in a glass vessel, and supplied it with spring water; the fish lived in this manner for fifteen months, grew to more than double the size it was when first confined, and threw out much feculent matter. Lest it should be supposed the fish lived on substances held in the water by solution, he used distilled water and impregnated it with the air of the atmosphere, and put other gold-fish in the water thus treated, and kept them six months,[3] during which time they threw out feculent matter, and thrived as before mentioned.

In referring to the "action of the mind" on the secretion of saliva Young makes the following comment in a foot-note:

> Is not the secretion of the saliva and gastric juice synchronous? It is highly probable from long habit, the actions of these two sets of vessels become associated; hence, when the stomach and its vessels are irritated, as in nausea, there is always a flow of saliva, though nothing stimulating has been applied to the mouth. The excitement of the vessels of the one seems to keep pace with that of the other; when the nausea is so great that vomiting is just at hand, the flow of the saliva is proportionally increased; and when we make an unsuccessful effort to vomit, we generally throw out a mouthful of saliva.

Is it far-fetched to recall in this connection the comparable psychic secretion which has been described in recent years for both saliva and gastric juice and the probability of a common stimulus for the production of each?

Let us now consider more particularly Dr. Young's observations on the processes in the stomach. He assumes that sufficient evidence was already at hand from experiments on animals to permit plausible, if not conclusive, inferences concerning our own digestion. He writes:

> It would be unnecessary to recite particular experiments, to prove the solvent property of the gastric fluid, this being admitted on all hands. . . . The effects of solution are most remarkable in such animals as swallow their food without mastication; we will, therefore, relate a few experiments made on some of these.
>
> Our common large bull-frog (*Rana ocellata*) was chosen in order to observe the effects of the gastric fluid, as they swallow all their prey whole. They have a large membranous stomach, which when distended, occupies the whole anterior part of the abdomen: the œsophagus is very wide, so that their food can be examined at pleasure. Two of a very large size were procured, and their stomachs were found to be greatly distended with food: being desirous of seeing what was their natural aliment, and the effects of their digestive power upon it, by means of a pair of forceps, one of their stomachs was easily emptied of its contents; and to my surprise, and that of others who witnessed the fact, it was found to contain a common sized spring frog, and afforded a fine oppor-

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[3] One is reminded of J. Loeb's demonstration nearly a hundred years later that certain fishes can be put into distilled water without the least injury.

tunity to see the effects of their gastric liquor. The whole external surface of the frog was acted upon, the muscles having, superficially, quite lost their texture; some parts of the backbone were bare, the spinous processes of which were quite soft. Upon introducing a forceps, a second time, the hinder parts of a second frog were found, which shewed the effects of their fluids in a still greater degree: the muscles of the thigh were reduced to a complete jelly, though still retaining their form; some parts of the bones that were covered with flesh were quite soft and flexible. Upon extracting the contents of the stomach of the second frog, it was found to contain a field mouse, about a third larger than our common mouse: its whole surface was quite soft, having entirely lost its texture; the fore legs were nearly disconnected from its body, the bones of which were soft; the bones of other parts of the body were also examined; they were all soft. But what was most surprising, the teeth of this animal did not escape; the incisors were, as Dr. Jacobs witnessed, soft and flexible, having the appearance of a piece of half dried tendon. Neither the frog nor the mouse had any acid or putrid smell.

It appeared very evident from the preceding experiment that the fluids of these animals acted upon bones; but in order to ascertain whether they could dissolve them completely down, the following experiment was performed. The head and all the bones of the mouse were cleared of their flesh, and forced into the empty stomach of one of the frogs; he was then put into a jar of water. In two days, the bones were all discharged in the form of a mortar; by rubbing it between the fingers, small pieces of bone were distinguishable. This will serve to shew us the powerful action of an apparently inert fluid on an animal matter, sparing not bones, nor even the teeth of animals.

Being desirous of knowing the length of time they would require to dissolve down a small frog, the following experiment was performed. A packthread was tied to the hind legs of a living spring frog; its head was then put into the mouth of one of the large frogs; as soon as he felt it move it was swallowed greedily. In five hours it was drawn up by means of the thread; the skin and external surface of the muscles were tender. It was again introduced; in the space of seven hours, it was drawn up a second time; the abdominal muscles were now dissolved, and the intestines had protruded; the bones of the feet were soft, and separable from the leg by the least force; in a word, the whole was a complete dissolved mass. It was swallowed a third time, and attempted to be drawn up in six hours afterwards; but it had so far lost its texture that the two legs, to which the thread was tied, could only be brought up; the bones of these were soft and flexible, as before mentioned. Many experiments of this kind were made to see the effects of their gastric menstruum: in many cases, after giving them small frogs, the trunk and head of these animals were drawn out of their stomachs complete skeletons, but the bones were always soft, and felt like tender cartilage. In all the half-digested substances which were at different times taken from their stomachs, as frogs, veal, beef, etc., an acid was constantly found present: they were seldom examined before two hours after being swallowed; at this short interval when their surfaces were touched with litmus paper, it was turned red.

Snakes, like the large frogs, also swallow their food without mastication: many experiments were therefore also made on them, by forcing frogs, lizards, etc., into their stomachs, to see the effects of solution: they agreed in every respect with what has been said of frogs, like them perfectly dissolving down entire animals. The only difference between them was, that the solution of snakes went on only about half as fast as that of the large frogs.

The gastric fluid of man and that of frogs and snakes agree perfectly in their action on flesh, as the experiments of Spallanzani prove that the first of these powerfully dissolves meat out of the body. As the menstruum of the two latter animals acted so uniformly on bones, it appeared highly probable the fluid of our own stomach would also. To ascertain this, the condyles of the thigh bone of a chicken, weighing eleven grains, were swallowed; the bone remained a considerable time in the stomach, as was supposed from some uneasy sensations that were occasionally experienced for between two and three days; the fourth day it was discharged, reduced to a shell, weighing only three grains. Thus far the digestion of man and these animals perfectly agree, in solution being the first step towards the conversion of food into chyle; but they differ in some particulars, and probably by attending to these, they may be of use to us.

First. They are cold-blooded animals: heat is a powerful agent in all solutions, and the experiments of Spallanzani prove it greatly assists the action of the gastric liquor out of the stomach.

Secondly. They do not masticate their food.

These two inconveniences are obviated, by these animals never drinking when their digestion is going on, so that their fluid acts in its undiluted state; whereas in man, it is always diluted, as he seldom eats without drinking. That this was the case with these animals I had clear proof; for although I examined the contents of their stomachs so often, in no one case could I find any fluid more than a jelly-like substance, appearing to be made up of gastric juice and dissolved flesh. Supposing, however, that the pressure used in bringing up the food of the frogs might have forced the more fluid parts into the duodenum, I resolved to ascertain the fact in another way; this was easily done. A teaspoon could readily be passed into their stomachs, and with this the dissolved food could all be brought up; it was always, however, of the consistence above mentioned. During the time these experiments were made, they were constantly kept in large jars of water. The attention to this circumstance by these animals, which swallow their prey entire, is a necessary part in their digestion, as they require a very powerful menstruum, so as to dissolve not only entire muscles, but also bones. The inference we would draw from it would be, to attend occasionally to what necessity urges them to observe constantly. Thus when our stomachs are weak, or we are troubled with dyspeptic symptoms, like them we ought to avoid much diluting our gastric juice; so that although it were secreted not perfectly healthy, yet having the advantage of acting in its uncombined state, solution and digestion may go on, when it otherwise would not, with the common quantity of drink. Indeed our stomachs in this respect act a kind part to us; for when we make our first dish on broth it seldom relishes much solid aliment after it; hence soups are the first dish at the table of the temperate, and the last at that of the epicure.

Both Spallanzani and Réaumur believed that vegetable food is less easily digested by certain animals than meat. Young reinvestigated this question on frogs. He found that when peas, beans, wheat and bread enclosed in linen bags were introduced into the stomach, all but the bread were still entire at the end of thirty hours; but when the peas and beans were well bruised before introduction they were dissolved. The author concludes that the *living principle* in the seeds resists digestion. In harmony with this view he found that seeds would germinate when retained in the stomach. An entertaining story is cited from the Italian anatomist Morgani.

> He informs us that a young lady living entirely on vegetables (it being lent), was seized with a violent affection of her stomach, and great emaciation ensued. Different medicines were used, but without the least alleviation of her symptoms. At length a violent vomiting commenced, and to the astonishment of all present, she threw up a small plant, with perfect leaves and roots! This at first sight might be looked upon as approaching the marvellous; yet why should we doubt it? The authority of our author is as respectable as any other of our profession; and we have just seen that seeds will vegetate when retained a sufficient length of time in the stomach. The probability here was, that the young lady had swallowed the seed of some small plant, without destroying its texture by mastication; which being retained in the stomach, and exposed to heat and moisture, vegetation progressed.

Vegetable and animal foods alike are, then, capable of solution by the gastric fluid, provided that their "organization or vital principle be previously destroyed." One could thus believe the further evidence that "a respectable gentleman" had seen two polar bears "that had subsisted on vegetable food alone, from the time that they were taken from their mother's breasts; and that they were more than half grown, and very fat." On the other hand, he cites the case of the Italian naturalist who "by dint of hunger learnt a pigeon to eat meat of which it became so excessively fond, that it preferred it to every other kind of food, even to wheat, which in their natural state, they eat before anything else."

Will simple solution by the powerful action of the gastric fluid explain the conversion of "aliment into chyle?" asks Dr. Young. Many earlier teachers had assumed that activities which we now know to be associated with microorganisms play a part. The warmth and moisture of the body would facilitate this fermentation and putrefaction. Our author writes:

> Chemists divide fermentation into three kinds, the vinous, acetous and putrefactive; the product of the first is vinous spirit, or alcohol; of the second, acetous acid, or vinegar; of the third, ammoniac, or volatile alkali.
>
> In order to ascertain whether a vinous fermentation could take place in the human stomach the following experiment was performed. My friend, Mr. Mitchell, avoided his usual breakfast, in the place of which he took, between the hours of eight and ten, twelve ounces of sugar. Nothing more was taken until one o'clock. Having the power to ruminate, it was at this hour thrown up; the mass was sweet: upon being put to rest no intestine motion or disengagement of air was to be perceived. It was then submitted to distillation: a limpid fluid passed over into the receiver, which was sweetish, but had none of the properties of a vinous spirit. Carbonic acid gas is constantly evolved during the vinous fermentation; Mr. Mitchell, therefore, paid particular attention to this, as long as the sugar was on his stomach; but there was not the least eructation of air during the whole period the experiment was going on. If ever a vinous fermentation took place in the stomach, we expected to have found it in this experiment; as this viscus was plentifully supplied with saccharine matter, which passes so readily to this state; but as nothing of the kind occurred, we conclude the vinous fermentation has nothing to do with the digestive process.

Young's experiments on frogs had already taught him, in confirmation of Spallanzani, that the gastric juice resists decay and it "even restored putrid substances to their original sweetness." Here is an additional experiment upon himself:

> On an empty stomach I made a light dinner, on chicken pye, and drank simple water: in half an hour, by irritating my fauces, it was thrown up; at this time it was plentifully supplied with gastric fluid, as well as saliva, as the quantity of food was but small. It was then exposed in a tumbler to a heat equal to the human temperature. For the space of nine hours there was not the least intestine motion nor any disengagement of air. As digestion is performed sooner than this period, it was not attended to any longer.

Young convinced himself of the acid character of the gastric fluid and attempted to identify the acid present.

> A piece of fresh veal was introduced into the empty stomach of one of the large frogs: in two hours it was examined; the surface was a little tender; upon being touched with litmus paper it was turned red. Here digestion was progressing quite regular, yet an acid was present. It appeared impossible at the same time to conceive the meat could become sour in so very short a time, and in so very low a temperature; it was therefore conjectured, the acid was to be referred not to the meat, but to the gastric juice, which the following experiments confirmed us in. A frog was kept starving for two days; a piece of litmus paper was then forced into its empty stomach by means of a pair of forceps; upon being drawn out, it was covered with gastric juice, and the litmus turned red. The naked gastric juice was afterwards often examined, by bringing it out of their stomachs with a teaspoon, and constantly found to be slightly acid. Being thus fully persuaded the acid, in the digested food of frogs, did not arise from a fermentation, but was to be referred to their gastric juice, we were led by analogy to suppose the acid of our own stomachs was to be attributed to the same origin: but this analogical reasoning might be called mere probability; the following experiment was therefore performed. Early in the morning, my stomach being empty, I irritated my fauces with a view of throwing up some gastric juice: though many efforts were made, none could be vomited. The following day I took some meat on an empty stomach: in half an hour afterwards, by irritating my fauces, the meat was thrown up, and with it some gastric fluid: upon being tested, an acid was very evidently present. Here no one can suppose the acid was to be referred to the meat. We have little hesitation, therefore, in saying that the acid so constantly found in the stomach of man, and almost, probably, all animals, is to be referred to their gastric fluid.

Young's friend, Mr. Mitchell, "being in good health and having the power to ruminate," collected gastric fluid for him. The analysis of the filtered fluid was performed by precipitating with acetate of lead. The precipitate was treated with muriatic acid "which decomposed it, a very white powder remaining at the bottom, and a fluid above." From analogy with the behavior of urine similarly treated the author concluded:

> Though great accuracy and many varied experiments are required to ascertain certainly the presence of an unknown acid, yet we are disposed to believe any person who had witnessed the great similarity in the comparative precipita-

> tions just mentioned would have pronounced the same explanation was to be applied to both, or that the acid in the filtered fluid was the phosphoric.

Additional evidence of the presence of phosphoric acid was believed to be derived from the behavior of the fluid towards solutions of mercury or silver in nitric acid and towards lime water.

The supposed finding of a mineral acid led Young to comment upon the efficiency of metallic iron recommended by Italian physicians as a tonic, its solution being thereby explained. For, he asks, "does not the uniform effects of iron in its metallic state prove that an acid is always present in the stomach?"

The solvent property of the gastric juice on bones and teeth suggested the possibility of its use as a solvent for stone in the bladder.

> A calculus was obtained from Dr. Jacobs of a very firm texture weighing exactly fifty grains. It was introduced into the stomach of one of the large frogs. In two days it was taken out for examination: at first sight it was evident solution had taken place, for the gastric juice which adhered to it was coloured with some of the dissolved stone: it was found to weigh forty-five grains. It was forced into the stomach a second time, where it remained for two days; it now weighed thirty-eight grains: from this, it appears, it is well worthy of more attention. When introduced into the bladder, with the heat of the human body, we have little doubt the gastric juice of frogs would act upon calculi with much effect. The fluid is easily procured, and without the necessity, as in other animals, of sacrificing a life every time we wish to obtain it: by means of a teaspoon it is readily brought up from their stomachs.

With the theory of fermentation rejected, the author proceeds to attempt an explanation of the digestive function.

> Aliment is dissolved by the gastric menstruum; it then passes into the duodenum and meets with bile and pancreatic liquor; after being united with these, a heterogeneous mass is formed called chyme, and from this the lacteals secrete chyle.
>
> We are led to believe this to be the true doctrine, because, as before observed, simple solution will not explain the phenomenon of digestion; nor will the mixture of this dissolved mass, with bile and pancreatic liquor, change it into chyle; for we know chyle is formed when both these fluids are wanting: thus nutrition goes on when the biliary ducts are obstructed, and also when the pancreas is schirrous. That the absorbents have a secreting or digestive power, we learn from the following. Dr. Wistar informs us of a remarkable case, which occurred under his own observation, of a person who was supported for many weeks, by nourishing enemata, alone. Here it can not be said there was bile, gastric and pancreatic liquors to assimilate the injected fluid into chyle; yet chyle was formed and the system nourished. If the lacteals acted the part of simple absorbing, or capillary tubes, their contained fluids ought to partake of the sensible properties of the mass from which they are absorbed. But the reverse of this is the case: chyle has always the same taste, however different the sensible properties of the contents of the intestines may be, whether they are acid, bitter, etc. We draw a strong argument in truth of this opinion, by turning to the vegetable kingdom, throughout the whole of which the digestive process is seated in the absorbents. Water is to them what the fluids of the primæviæ are to the digestion of man: it dissolves their

> food, which being exposed to their vessels is taken up; but the fluid thus taken up can not be imitated by any mixture of earth and water, any more than we can imitate chyle by combining aliments with the fluids of the alimentary canal. As we thus have proofs the one is a secretory process, why not admit that of the other to be so also, since the circumstances of each so perfectly agree.

One hundred years later the obscure importance of the absorbing alimentary tract must still be emphasized. In the words of a popular textbook: the energy that controls absorption resides in the wall of the intestine, presumably in the epithelial cells and constitutes a special form of imbibition which is not yet understood. Thus the dignity of the living structures still remains unchallenged.

The uncertainty regarding the acidity of the gastric juice which still prevailed twenty years after Young's paper was published has already been mentioned. Even as late as 1812 Montegre insisted that what was supposed to be gastric juice is nothing but swallowed saliva. An American, Professor Smith, suggested that digestion is performed "by the *veins* of the stomach, and by the *liver*." Vague ideas like these, in contrast with modest experimental inquiries illustrated by the monograph which we have reviewed in some detail, led Dr. Beaumont to remark:

> It is unfortunate for the interests of physiological science that it generally falls to the lot of men of vivid imaginations, and great powers of mind, to become restive under the restraints of a tedious and routine mode of thinking, and to strike out into bold and original hypotheses to elucidate the operations of nature, or to account for the phenomena that are constantly submitting to their inspection. The process of developing truth, by patient and persevering investigation, experiment and research, is incompatible with unrestrained genius. The drudgery of science is left to humbler and more unpretending laborers. The flight of genius is, however, frequently erratic.

THE INSTRUMENTS AND METHODS OF RESEARCH[1]

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WERE I to accuse you of forgetfulness, of shortness of memory, or possessed of that quality apt to prove troublesome to others, though characterized by the oldest of our past presidents, in his delightful "Reminiscences of an Astronomer," as a valuable quality—absent-mindedness—I dare say you would not be much offended, though possibly a trifle annoyed. But were I to accuse you of *narrow*-mindedness I might meet with a different reception. To none of us would it matter much to be called short-memoried or absent-minded, but to be termed *narrow-minded* arouses our resentment immediately. But are we not all necessarily so, more or less, according to the circumstances in which we find ourselves?

Mind the Chief Instrument of Research

I believe it was the mathematical physicist Stokes who warned us we must not forget that the chief instrument of investigation—the mind—is itself the object of research. To the mind, then, we should devote our first and chief attention in the discussion of the subject for this evening. How to reduce and check as far as possible this natural tendency of all of us to narrow-mindedness in one or more directions, or how, realizing its necessary existence, to make due allowance for it in the formulation of conclusions which, though drawn with utmost care, are nevertheless subject to "personal equation," is, as we at once readily see, a matter of the very highest importance.

Many of you are doubtless familiar with the Hindoo fable set to rhyme by Saxe:

It was six men of Indoostan
To learning much inclined,
Who went to see the Elephant
(Though all of them were blind),
That each by observation
Might satisfy his mind.

The *First* approached the Elephant,
And happening to fall
Against his broad and sturdy side,
At once began to bawl:
"God bless me! but the Elephant
Is very like a wall!"

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[1] Address of the retiring president, delivered before the Philosophical Society of Washington, Saturday evening, December 5, 1908.

The *Second*, feeling of the tusk,
  Cried, "Ho! what have we here
So very round and smooth and sharp?
  To me 'tis mighty clear
This wonder of an Elephant
  Is very like a spear!"

The third, happening to grasp the "squirming trunk within his hands," declared the elephant to be "very like a snake"; the fourth, feeling "about the knee," thought the elephant seemed "very like a tree"; the fifth, "chancing to touch the elephant's ear," described him as being "very like a fan," and when within the scope of the sixth came the swinging tail, the fact that the elephant "is very like a rope" was to him proved beyond dispute.

And so these men of Indoostan
  Disputed loud and long,
Each in his own opinion
  Exceeding stiff and strong,
Though each was partly in the right,
  And all were in the wrong!

And now, if you will permit me to slightly alter the poet's last verse, so as to point the moral to our own selves:

How oft in scientific wars
  We disputants are seen
To rail in utter ignorance
  Of what each other mean,
And prate about an Elephant
  Not one of us has seen!

WHAT IS RESEARCH?

In this day of encyclopedias numerous and ponderous, one is often struck with the fact that in spite of the manifest care and conscientious thought bestowed by the responsible editors, the omissions and evidences of discontinuity of treatment, and lack of recognition of the prime purposes of the compilation are as noteworthy as the imposing array of the results of our steadily advancing knowledge is startling. For a philosophic treatment—one fully appreciative of that which the student really requires, not only to enlighten him with regard to a particular subject, but also to stimulate him to research where it is most needed—I frequently get more satisfaction out of the older encyclopedias than from our modern ones, even though they can but present the status of the subject up to the time they were written.

As an illustration, take the word "research," appearing in our topic of this evening, or any of the associated terms—"discovery," "experiment," "investigation" and "observation." Turning to the index volumes of the ninth and tenth editions of the "Encyclopedia Britannica," I find but two references in which the word "research" appears—one to the exploring vessel, the *Research,* and the other to "research degrees." Turning to the page on which the latter occurs, we find this interesting statement referring to Oxford University:

> New degrees for the encouragement of research, the B.Lit. and B.Sc. (founded in 1895, and completed in 1900 by the institution of research doctorates), have attracted graduates from the universities of other countries. In 1899 a geographical department was opened, which is jointly supported by the University and by the Royal Geographical Society.

Now comes the interesting statement which I beg to emphasize:

> *Of more bearing on practical life are the Day Training College Delegacy (1892) and the diploma in education (1896). Under the former elementary school teachers are enabled to take their training course at Oxford, and do so in growing numbers,* etc.

We thus see what the writer of this article thinks of the relative value in practical life, of research foundations and normal school foundations! Yet we all know that this view is not typical of that held in a country having such productive research organizations as the Royal Society or the Royal Institution. Sir Norman Lockyer, in his luminous inaugural address before the British Association for the Advancement of Science, in 1903, on the "Influence of Brain-power on History," says: "A country's research is as important in the long run as its battleships." Why, then, does not the standard encyclopedia of that country make space for a representative article on "research"?

Under "investigation" there also appears absolutely nothing. However, we have the ship, "Investigator," Investigator Shoal, Investigator Group, etc., but not a word about the general methods employed by "scientific investigators." And so it is with the word "discovery"—there is no reference whatsoever to an article on the general principles leading up to discoveries. Likewise with the word "observation"; though there are many references to observations of various kinds, there is no one article for setting forth the general principles of "observations" or the part they play in the discovery of fundamental facts. The same experience is had with regard to the word "experiment."

Now let us turn to an encyclopedia I invariably read with pleasure and profit; it frequently has supplied me with references to earlier work not to be obtained elsewhere. We shall find it instructive to us to-night, though the articles to which I beg to invite your kind attention were written three fourths of a century ago. I refer to the classic Gehler's "Physikalisches Wörterbuch"—the revised edition by the noted investigators Brandes, Gmelin, Horner, Littrow, Muncke and Pfaff, in 20 volumes and published in Leipzig, 1825–1845. A veritable fund of information is found under the headings "Beobachtung" (observation) and "Versuch" (experiment). The article on "Beobachtung," by the physicist Muncke, embraces 28 octavo pages. He shows the distinction between "Beobachtungen" (observations) and "Versuche" (experiments) to be that the former pertain to the perceptions of phenomena presented to us by nature in her unmodified course, whereas in the latter—in the experiments—we are seeking to produce certain results or phenomena, more or less looked for, in order either to verify a law already known or to disprove one suspected of being wrong or even to discover a new one. Both classes of experiences are necessary for a piece of investigation or research work.

Thus, we may behold either visually or in some other way certain striking solar phenomena; these belong to the class of observations which we ourselves are unable to modify in any manner whatsoever. Continued observation may, however reveal a certain law which by experiment in the laboratory, conducted along more or less definite lines, we may seek to imitate in the hope of getting some clue to the *modus operandi* of the observed phenomena. In this article on "Observations" the author treats in detail the various elements entering into correct methods of investigation, condition of the observer and of his senses, his being unbiased, character and errors of the instruments, errors of results, methods of increasing accuracy, representations of observations by graphs and formulæ, method of least squares, etc. He points out the mistake sometimes made, that an established formula satisfying the observed phenomenon within certain limits represents an actual law of nature.

The article "Versuch" (experiment) consists of 44 pages and is contributed by the astronomer Littrow. He shows that the most rapid development takes place in those sciences which afford the greatest opportunity for experimentation, referring, *e. g.*, to the slow and painful progress of the astronomer as long as he had to confine him self to mere celestial observations and the comparatively rapid strides which occurred as soon as some of the observed phenomena could be either imitated by, or be compared with, those derived by laboratory experiment. The investigator, he says, must be absolutely free from preconceptions and be careful, cautious and unbiased in his interpretation of what his senses may reveal to him. He illustrates how man, called jokingly "das Ursachenthier" (the animal ever bent on ascertaining the cause of things), proceeds in ferreting out the why and wherefore of observed phenomena, and how his methods of circumspection develop with the advance of knowledge.

Though man can not determine the "Endursachen," or ultimate causes of things, the field open to him to discover the laws governing phenomena or, *vice versa,* classifying and enumerating those which follow a certain revealed law, is, nevertheless, still very large and sufficient to tax his energies. Witness, for example, the host of observed phenomena obeying the law of inverse squares!

The remaining sections of Littrow's article deal with the reduction of the experiments to the laws of motion, the numerical expression of the observed results in definite units, the importance of the part played by instruments or mechanical appliances, derivation of laws governing the observations, methods of ascertaining these laws, methods of reduction and of publication, and errors to be avoided.

These two articles will show sufficiently the character and scope of similar ones we should like to see in our standard English and American encyclopedias.[2] Such information is contained in some measure, at least, though not as comprehensively, in the modern German book of reference, Brockhaus's "Conversations-Lexikon," as also in the "Grande Encyclopedia" of the French. It is truly remarkable that there should be such an oversight in our "International Encyclopedia," when it is remembered that the editor-in-chief was one to whom research work owes a very great debt of gratitude indeed—the late and greatly lamented Daniel Coit Gilman. The only article found is one on "expert," and this pertains chiefly to "expert evidence" in courts of law. Yet what better statement concerning the "research or scientific spirit" could be made than contained in the following quotation[3] from Gilman's writings?

> It is perpetually active. It is the search for the truth—questioning, doubting, verifying, sifting, testing, proving, that which has been handed down; observing, weighing, measuring, comparing the phenomena of nature, open and recondite. In such researches, a degree of accuracy is nowadays reached which was impossible before the lens, the balance, and the metre, those marvelous instruments of precision, had attained their modern perfection. Wherever we look we may find indications of the scientific spirit. The search after origins and the grounds of belief, the love of natural history, the establishment of laboratories, the perfection of scientific apparatus, the formation of scientific associations, and the employment of scientific methods in history, politics, economics, philology, psychology, are examples of the trend of intellectual activity. The readiness of the general government and of many State legislatures to encourage surveys and bureaus, the establishment of museums of natural history, and the support of explorations illustrate this tendency. Even theology feels the influence. The ancient and sacred proverb has been rediscovered —the letter killeth and the spirit maketh alive. I will go only to the edge of this disputed territory and shelter my own opinions behind those of a learned devout prelate of the English Church (Bishop Walcott), whose words are these: "No one can believe more firmly than I do that we are living in a time of revelation, and that the teachings of physical science are to be for us what Greek literature was in the twelfth century." . . .

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[2] "Chamber's Encyclopedia" is found to contain a short article on "Experiment"; also one on "Observation."

[3] Extracts from the "Launching of a University," 1906, pp. 147–150.

With the growth of the scientific spirit grows the love of truth, and with the love of truth in the abstract comes the love of accuracy in the concrete.

Our foremost English dictionaries are in general not any more satisfying or edifying regarding the precise meaning of "research" in the scientific sense than are the standard encyclopedias. Their illustrations of the use of the word are usually neither apt nor sufficiently comprehensive.

How may we sharpen Our Senses?

Of the senses, *sight* plays the greatest part in investigation. To this organ we have thus far devoted most attention to supplement and increase its natural powers by mechanical means—the telescope, microscope, etc. Next would rank the sense of *hearing;* but the appliances for increasing our sensations in this respect are comparatively few, and still more is this the case with regard to the senses of *taste, smell* and *touch.*

Yet what truly wonderful powers of touch are developed by the blind, and how extraordinary are the capabilities of certain animals for foretelling the distant approach of a deadly foe by the means of hearing or of smell! There are well-authenticated cases on record where animals unquestionably appear to have "felt" the coming of a great natural catastrophe, like an earthquake, several hours before any human being had the same knowledge.

Might not man also, to his advantage, increase or stimulate his less-used senses in some manner, to the same degree or approximately so, as that of sight? If he did, is it not possible that thereby he might have perceptions which would materially assist him in solving some of the vexed riddles of the universe? May he not, for lack, of proper development of these senses, be in much the same plight as the "six men of Indoostan to learning much inclined who went to *see* the elephant, though all of them were *blind*"?

If there is some possibility in this direction, how about the power of stimulating or interpreting our muscle sensations, the sensations of heat and cold, of pain, of pleasure, etc.? Efforts have been made, as you know, to trace a definite connection between certain atmospheric phenomena and bodily sensations, or between the impelling motives to commit suicide or other crimes and certain meteorological conditions. Likewise are there attempts by well-known men of science to sharpen and interpret the psychic sensations.

There is revealed here a field of research but little explored as yet —the increase of our powers of perception along other lines than chiefly those of sight. No one can foretell the future possibilities in these directions.

The doctrine of evolution teaches the result of long-discontinued use of any particular organ, and has familiarized us with the wonderful achievements of nature brought about by sustained and continued effort along some definite direction. Both the physical and the psychic conditions of the observer require their highest and healthiest development to insure not only the best results with the ever-increasing accuracy or precision required by the steady advance of knowledge, but also to bring about that round- or broad-mindedness needed for the proper interpretation of the results observed.

The Mathematical Instruments of Research

A good-sized chapter might be written on the "Mathematical Instruments or Tools of Research." The predominating tendency of resolving or expressing every natural phenomenon—periodic or otherwise—by a Bessel or a Fourier series or by spherical harmonic functions has brought about at times, especially in geophysical and cosmical phenomena, if not direct misapplications, at least misinterpretations of the meaning and value of the coefficients derived. Like a certain class of "naturalists," we also may have laid ourselves open to the approbrious term of "nature-fakir," and instead of clarifying the situation our calculations may have actually contributed instead to "befog" it.

Frequently by the purely mathematical process there have been eliminated, in the attempt to represent a more or less irregularly occurring natural phenomenon by a smoothly flowing function, the very things of chief and permanent interest. The normal or average diurnal temperature curve, for example, or a uniform magnetic distribution over land, so as to yield perfectly regular lines of equal magnetic declination, never occurs in nature. There is thus being impressed upon us more and more forcibly the fact that what we have been regarding as "abnormal features"—the outstanding residuals between observations and the results derived from the mathematical formula—are in truth not "abnormal" from the standpoint of nature, but are rather to be taken as indicative of the "abnormality" or "narrow-mindedness," which means the same thing, of ourselves in trying to dictate to nature the artificial and regular channels she should pursue in her operations.

Louis Agassiz said:

> The temptation to impose one's own ideas upon nature, to explain her mysteries by brilliant theories rather than by patient study of the facts as we find them, still leads us away.

The fundamental law of nature is to invariably follow the paths of least resistance, and by examining these lines of structural weakness of the opposing systems we may have opened to us the very facts which are to be of real value and of sure benefit to mankind.

The irregularity of the banks bordering a natural watercourse serves to differentiate the work of nature from that of the builder of the artificial and regular channel.

No, instead of rejecting, we must learn to retain the outstanding residuals and study them most carefully and regard *them* as the true facts of nature, and not those which we so egotistically and presumptuously try to force on her. What great discoveries may lie open to us when we once have grasped the true significance of the facts we have been so fond of measuring by our own standard and have been terming as "abnormal" or "irregular"!

An interesting example of not wholly successful application of the continuous and ever-recurring functions of spherical harmonics to a typical geophysical phenomenon—the distribution of magnetism over the earth's surface—has been discussed by the speaker elsewhere. Though the number of unknowns has been increased in recent computations from the original 24 of Gauss to 48, nevertheless the difference between theory and observation is of such an order of magnitude as to preclude the use of the formula for even the purely practical demands of the navigator and surveyor. Nor has any one succeeded in giving any physical interpretation of the laboriously derived coefficients beyond the first three. And what do these three stand for? The simplest possible case of a first approximation to the actual state of the earth's magnetism, *viz.*, that of a uniform magnetization about a diameter inclined to the axis of rotation!

The prime difficulty here may be summed up in a word. The very surface over which the spherical harmonic functions are spread is itself such a prolific source of disturbance as to cause effects embracing a continent, a state or a locality. Such a large number of terms would be requisite for an adequate representation as to make their computation prohibitive. We are dealing here with more or less non-continuous effects that cannot be imitated by continuous functions without leaving behind a train of residuals, precisely as though we were to try to fit to the actual configuration of the earth some standard pattern of our own. Let me ask what phenomenon have we, in fact, which will admit of the determination of 48, or even of 24, physical constants?

It had been my intention to say a few words on the value and limitation of that much-used as well as abused mathematical instrument of research, the method of least squares. Properly employed, it is a most useful adjunct to investigation; but, as intimated, the true significance of formulæ established by this method is at times pushed far beyond the limitations. What the tenor of my remarks might be will be sufficiently evident to you if I submit this query for your consideration: *What actual laws of nature have been discovered by the method of least squares?*

The Mechanical Instruments of Research

A few minutes were to have been given to the instruments employed by the scientific man to sharpen and amplify his natural senses and sensations—in a word, the tools furnished him by the mechanician. I am glad, however, both for your sake and mine, that this part of the subject was covered by an interesting paper presented at the previous meeting of the society. It was emphasized there that for the best results it is essential that the investigator be able to work with instruments so constructed as to permit him to control or renew the various adjustments without the necessity of returning the instrument to the maker. The principle at times employed, which assumes that when adjustments are once made they are to "remain put," is apt to prove a very pernicious one. A number of very interesting examples from my own experience in the purchase of magnetic instruments during the past ten years might be cited; but, as has been said, this part of the subject having already been covered, there is no need to dwell further upon it than to emphasize the injunction that the research worker, if he desires the best results, must know his instruments as thoroughly as himself.

Subjects of Research

We come next to a brief consideration of the *subjects* of research, though not specifically mentioned in the title of our paper, yet implied in it. The rapid progress made by a science as soon as it reaches the stage of experimentation has already been noted. A crucial experiment has at times furnished information which by mere observation of phenomena, running their natural and unmodified course, might either have never come into our possession or at best would have taken a considerably longer time than that of the decisive experiment. You are all familiar with such cases, for almost every science can furnish examples.

Now it is an extremely interesting and suggestive fact that the greatest experimental discoveries to-day are not made in the older, well-recognized sciences, but on their borderlands—in the "twilight zones" of more or less related sciences. I have but to mention the words "physical chemistry," "physical geology," "astrophysics," "biochemistry," etc., and you will readily grant the assertion made. In the overlapping regions there seem to be the greatest opportunities afforded for solid, thorough, and at the same time remarkably rapid, experimental achievements. And so we are having produced almost daily new specialties or new sub-specialties.

What is the effect on the general broad-mindedness of man by this extreme specialization, so necessary for the production of the best and most far-reaching results? *Is the modern specialist more narrow-minded than the generalist of a century or two ago?* In view of our opening statement that the prime instrument of research is, after all, the mind, the question is, as you see, not an irrelevant one. We find statements occasionally made which would imply an affirmative answer to our question; but I, for one, would most emphatically protest against such an inference. I should maintain that the specialist, other things being equal, is likely to be a broader man than he who has no specialty, but simply a general knowledge of some particular science. The reason for my positive statement would be found in the fact mentioned, that the greatest part of the research work to-day is being done on the border-lands of the general sciences; for he who wishes to take part in this very active competition must needs be far better equipped than the mere generalist. The physical chemist, to be most successful, must have a very intimate knowledge of both physics and chemistry, and the more mathematical skill he possesses the better. The astrophysicist must be a physicist, a chemist, a mathematician, besides being an astronomer. And so with regard to the geophysicist.

Only a few names need be cited—like those, for example, of Faraday, Maxwell, Kelvin, von Helmholtz, Mascart—to support the contention that the broadest physicists are, as a rule, those who have regarded their laboratory experiments and deductions therefrom merely as a means to an end, not an end in themselves, and who have accordingly sought to apply the knowledge gained to the solution of some of the great problems affecting the general welfare of man. There is the greatest need in this country of well-trained and well-equipped physicists in the solution of the many perplexing problems of the earth's physics with regard to the phenomena of seismology, vulcanology, meteorology, geodesy, atmospheric electricity, terrestrial magnetism, etc. When the investigator makes the attempt to apply some of his laboratory facts to geophysical and cosmical phenomena, he has opened to himself a world of which he never dreamed; he finds zest in familiarizing himself with the fundamental facts of other sciences in which until now he could take no interest.

METHODS OF RESEARCH; DISCOVERY OF LAWS

The methods in general have already received treatment in connection with the foregoing topics. It is always interesting to know what was the precise course followed in the discovery of a great law. However, no two investigators have ever pursued, or at least but rarely, precisely the same paths, and we must therefore be content with the statement of the general principles of research, such as has already been given.

A prevalent fault is observed in scientific publications whenever the investigator has had good training only on the observational side and but very little experience in scientific computing. He is very apt to violate one of the first and fundamental principles of good observing, *viz., to employ such a method or scheme of observing as will yield but one definite result, and that with the highest possible accuracy and with the least amount of computation.* Oftener than may be thought, schemes of observation are used which leave an arbitrary element to the computer, and in consequence a different result is forthcoming, according to who makes the computation. Had we time apt illustrations could readily be given from published works. *The point made, that the observer must also bear in mind the computation side, and work up his results as soon as possible, is of fundamental importance in research work.*

It may be worth while to consider briefly the insatiable desire of the analyst to "ring" in a series of sines and cosines to resemble the course of some natural phenomenon of which he does not know the exact law. Is this the old story over again, though in somewhat altered garb, of the epicycles and deferents of ancient astronomical mechanics, which received its highest development in the Ptolemaic System of the Universe? You will recall that Ptolemy, building on the suggestions of Appollonius and Hipparchus, supposed a planet to describe an epicycle by a uniform revolution in a circle whose center was carried uniformly in an eccentric round the earth. By suitable assumptions as to his variable factors, he was thus able to represent with considerable accuracy the apparent motions of the planets and to reproduce quite satisfactorily other astronomical facts. This was the artifice employed by the astronomer of the period before the modern and more subtle art of simulating nature, by the sine-cosine method, had become known.

What seemed so intricate and complex in Ptolemy's time could be expressed in very simple language indeed, when a Kepler discovered the true functions as embodied in his three fundamental laws. The present method of hiding our ignorance of the real law, which seems at times to exert such a mesmerizing influence over us as to make us mistake the fictitious for the real, reminds one of the old conundrum: "Patch on, patch on, hole in the middle; if you guess this riddle, I'll give you a golden fiddle." If the sine and cosine of the angle does not represent the curve of observation, patch on a sine and cosine of twice the angle; then, if necessary, thrice the angle; next, four times, and so *ad infinitum!* Now guess the riddle!

Of course I do not mean to discard this useful and in fact indispensable tool of research, but simply wish to call attention to its limitations and to the importance of not overlooking the fertile by-products, the residuals which, because of our neglect of them, may some day rise and smite us in their wrath. Each one of us at one time or another has doubtless established, by least squares, an empirical formula of some kind which so beautifully fits the observations as to make us bold and venturesome. Now comes a new observation, somewhat outside of the range for which the expression was established. Eagerly the test is applied, and we find, to our chagrin, that the formula on which so much work had been spent will not fit the new result, and that we have a "counterfeit" and not the real law.

A graphical process, like the crucial and decisive experiment, may at times reveal an essential fact that the mind of even the greatest of mathematicians has failed to extract from his formulas.

Let us suppose, for illustration, we are dealing with a phenomenon which almost entirely unfolds itself during the time between sunrise and sunset—the well-known diurnal variation of the earth's magnetism is a striking case of the kind. Following the usual method, the phenomenon is resolved into component parts with the aid of a Fourier series. The formula as generally adopted includes the four terms having, respectively, periodicities of 24, 12, 8 and 6 hours. For ordinary magnetic latitudes the striking result is obtained that the second term—the 12-hour one—is as important as the first, or 24-hour, one; so we might equally as well say "the semidiurnal" as "the diurnal variation of the earth's magnetism." In fact, as the semidiurnal term unfolds itself twice in 24 hours, it is in reality more important than the purely diurnal one.

Does the resolution into Fourier terms of a phenomenon of the kind given really prove their existence in nature? Can we conclude without question that in addition to the diurnal term we also have a semidiurnal one? Even with four terms, the series does not represent each hourly observation of the 24 with the same degree of precision. In fact, the residuals for the night hours are nearly of the same order of magnitude as the observed quantities. If the physical existence of the 12-hour term is not proved, then there is no need of racking our brains as to its physical origin.

The difficulty disclosed by this example is of the same kind as the one treated in spherical harmonics, *viz.*, that we are attempting to represent a more or less non-continuous function having a duration commensurate with that of the daylight hours by functions running smoothly through their individual courses for 24 hours.

Babbage, the inventor of the calculating machine named after him, said he once had the following question put to him: "Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answer come out?" Do we not at times attempt to put wrong premises into nature's machinery and then expect correct answers?

We can not close this section better than by quoting the following passage from the address of the first president of this society, Joseph Henry, given on November 24, 1877:

> The general mental qualification necessary for scientific advancement is that which is usually denominated 'common sense,' though, added to this, imagination, induction, and trained logic, either of common language or of mathematics, are important adjuncts. Nor are the objects of scientific culture difficult of attainment. It has been truly said that the "seeds of great discoveries are constantly floating around us, but they only take root in minds well prepared to receive them."

Henry's insistence on the application in our scientific work of "common sense" reminds one of Clifford's apt definition of science as being "organized common sense."

Publication of Results of Research Work

We come next to the question of publication of the results of research. I think it may be taken as almost axiomatic that whatever is worthy of investigation should be made known in some effective manner, so as to reach without question those concerned. The multiplicity of literature on any one subject or even on any small portion thereof is nowadays such that the worker finds it utterly impossible to keep abreast of publications, even those in his own field, to say nothing of kindred ones.

He is forced more and more to rely on abstracts—at least in so far as to direct him to that which he unquestionably must consult in the original, if possible. In my own particular line of work I rarely find that an abstract supplies all that is needed, and I almost invariably prefer to work directly with the original. I have heard similar statements from workers in other fields.

If it be true, then, that the investigator usually finds it necessary to consult the original publications, the next conclusion to be drawn is that the publication of any research work should, in general, be of such form and size as to permit the widest distribution possible, not only among the libraries and the principal seats of learning, but also among the workers and institutions immediately interested.

The scientific worker generally does not possess the means to purchase or to construct the instruments he requires for the prosecution of his work, and a book bearing in any way on the line of work to be pursued is as much to be considered part of his equipment as the purely mechanical tools. Indeed, I was told by the late von Bezold that Wilhelm Weber set his laboratory students to work by telling them, "Here are the instruments, and there are the *Annalen der Physik;* now go to work." The man of science usually wants his tools close by and within ready reach. He cannot afford to go to a distant library and then possibly find the book out. Private possession permits him, furthermore, to make marginal notes and references to enable him quickly to put his finger on the very thing needed.

Owing to these well-organized needs, there has grown up a courteous and friendly interchange of publications among coworkers and sympathizers in the same field that to my mind deserves the highest encouragement. The time has unfortunately gone when scientific investigators can write such delightful and voluminous letters as passed between the research workers of half a century and more ago. The present system of interchange of publications has necessarily taken the place, to a very large extent, of the early letter-writing. It is a system of gradual development along the lines of least resistance that it would be disadvantageous to contend against until some more effective means of intercommunication among scientific men has been devised.

But such free interchange of research publications can only be conducted to a limited extent and can embrace only certain kinds of publications, *viz.*, generally reprints or those of which the original cost for publication has already been borne in some manner, be it by a journal or by some research foundation. Larger publications, however, because of their expensiveness, must generally be restricted, for one reason or another, in their general circulation, with the inevitable result that the persons directly reached may be entirely out of proportion to the importance of the work undertaken.

Scientific men and scientific bodies could well afford to pause and consider the tremendous cost of publication and the rather frequent waste of money incurred. Why is it, for example, that when an explorer gives an account of his travels in an unexplored region for the commercial press he finds it possible to say what he wishes in an attractive and handy octavo form, but when he is working for an endowed institution he feels compelled to present his matter in an expensive, ponderous, quarto form, inconvenient to handle?

It should be noted that it is as important to make research work known as to do it. To get our friends to read the contributions we may make to science requires nowadays no little skill and diplomacy and an attractiveness of literary style on the part of the author not so essential in the days of less frequent printed works. The original purposes of important and costly expeditions are sometimes well nigh defeated or superseded, because of the delay in publication, ensuing from the elaborateness of the plan adopted for the reduction of the field results and the form of publication decided upon.

Reduction in the pretentiousness, size and cost of scientific publications appears to me to be one of the greatest needs of research to-day.

METHODS OF RESEARCH BY INSTITUTIONS

Some time could profitably be spent on a consideration of the general agencies engaged in furthering research work and the methods employed for doing so. Being, however, connected with a "research institution," I should consider myself incompetent to enter upon a free and unbiased discussion of the methods of such organizations for the furthering of research work. Suffice it to say that it appears sometimes to be overlooked that *the most valuable asset of a research organization is the research spirit of its workers,* without it no amount of funds could accomplish the desired end. My remarks will be chiefly confined to a brief discussion of the methods to be used in certain investigations of a world-wide character. Craving your indulgence once more, I shall take as an example the general magnetic survey of the earth as representative of the kind of world-embracing research enterprises I have in mind.

Alexander von Humboldt, whose mental grasp was extraordinary in more than one science, set forth the following plan in his "Cosmos" for a general magnetic survey of the globe.[4]

> *Four times in every century an expedition of three ships should be sent out to examine as nearly as posible at the same time the state of the magnetism of the earth, so far as it can be investigated in those parts which are covered by the ocean. . . . Land expeditions should be combined with these voyages. . . .*
>
> *May the year 1850 be marked as the first normal epoch in which the materials for a magnetic chart shall be collected, and may permanent scientific institutions (academies) impose upon themselves the practise of reminding, every twenty-five or thirty years, governments, favorable to the advance of navigation, of the importance of an undertaking whose great cosmical importance depends on its long continued repetition.*

Here was a noble project, universally conceded to be not only of the greatest scientific interest, but also of the greatest practical importance. Yet why is it that this grand plan has never been carried out by the foremost nations in friendly concert? Have our academies, as Humboldt suggested, never "imposed upon themselves the practise of reminding every twenty-five or thirty years governments, favorable to the advance of navigation, of the importance of an undertaking" of this character?

Instead of working along a common and definite plan, the magnetic operations hitherto have consisted of more or less isolated and incomplete surveys, independently undertaken by various nations and distributed over a great number of years. Not even for a single epoch has it been possible to construct the magnetic charts on the basis of homogeneous material, distributed over the greater part of the earth, with some attempt, at least, at uniformity. And as to the possibility of

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[4] The quotation is from E. C. Otté's translation of the "Cosmos," vol. II., pp. 719–720.

constructing the charts, with the aid of similar data, for epochs twenty-five or thirty years apart, as Humboldt had dreamed, this, in spite of the enlightened interest of many countries, is even more remote.

Why should it have remained for a purely *research* organization to undertake a problem touching so keenly, as this, on even the so-called sordid, highly practical interests of man? It is a fortunate fact that Humboldt's fascinating international scheme failed of execution, and that the chief brunt of the work is now being borne by a single organization? It is not for the speaker to attempt to answer. The magnetic work of the Carnegie Institution of Washington has embraced, since 1904, a general magnetic survey of the Pacific Ocean, and land observations have been made in more or less unexplored regions in different parts of the world. The ocean magnetic work is to be undertaken next in the Atlantic Ocean, in 1909, on a specially built vessel, the first of its kind.

It is believed that an effective scheme of operation has been evolved, with the aid of the valuable advice received from eminent investigators. Without danger of giving offense to any one, it is possible to deal directly with the officials concerned, submitting to them our plans and ascertaining whether they contemplate doing anything similar, and, if so, whether, in case their funds are insufficient, they could suggest some friendly basis of cooperation between their organization and ours. This plan of action has met with entire success thus far. Duplication, overlappings and possible jealousies are all avoided; and in countries where no organization whatever exists to do the work, we are free to go ahead and finish the task in less time than it would necessarily take to get an official action or official consensus of opinion from a large scientific body.

Slow deliberation in terrestrial magnetic work would be disastrous, for the prime reason that the phenomena of investigation in this field of research are continuously undergoing change. The time-element in the earth's magnetism, even for a period of a few years, is of such moment as to completely mask the fine, hair-splitting points which would necessarily and rightly have to be raised on some international mode of action, to say nothing of the painful and cumbersome method which would have to be employed to conform with the rules of official correspondence between nations. Many a well and carefully executed magnetic survey in the past has had its full importance for world-wide investigation destroyed because of the possibility of error in the secular variation corrections which must be applied to bring its results up to date.

Though I may be judged guilty of defending my own policy, I believe the course pursued by the Carnegie Institution of Washington in conducting the general magnetic survey of the globe is the only way in which this particular project, and similar ones to it, could not only be expeditiously conducted, but so as to realize the chief objects of the work. Judging from individual expressions received from scientific men everywhere, they appear in agreement with us. This policy, briefly stated, is: To make, with the aid of the friendly and harmonious cooperation of all concerned, a rapidly executed magnetic survey of the greater part of the globe, so that a general survey, all-sufficient for the solution of some of the great and world-wide problems of the earth's magnetism, will be completed within a period of ten to fifteen years. At a smaller number of points, selected in consideration of the prime questions at issue, the observations are to be repeated at intervals of five years or less, in order to supplement the rather sparsely distributed magnetic observatory data. Thus the determination of the corrections for reduction of the general work to any specific date is continuously provided for.

Now, had I the time or were this the place, I should like to add a paragraph regarding the needful accuracy and the prime questions to be considered in the conduct of such a piece of work. Permit me to say that the most evident result of all magnetic work in the past is that, for the purposes of a general survey, it is far better to make some sacrifice in accuracy if thereby it is made possible to secure observations at another point. In other words, the errors due to local disturbing conditions are far greater than the purely observational ones. *Hence multiplicity of stations rather than extreme accuracy and laborious methods of observation and reduction is the prime requisite in magnetic survey work.*

STIMULANTS TO RESEARCH WORK

Dr. Gilman, in his charming reminiscences of the non-resident lecturers of the Johns Hopkins University, related the following of the great mathematician Sylvester:

> Sylvester enjoyed stimulants—I do not mean such vulgar and material articles as alcohol and coffee. I never saw any indications that he cared for their support. But he loved such stimulants to intellectual activity as music and light, lively society, in which he was not called upon to participate. Once at a symphony concert I sat just behind him, admiring the dome of his capacious cranium, unconcealed by hair, and I noticed how absorbed he was. The next day, Sunday, he came to me impetuously to say that he had worked out some mathematical proposition at the concert of the evening before, the music having quickened his mathematical mind. He really thought this was his greatest achievement yet, and he had hastened to write it out and mail it to the Academy of Sciences in Paris. Once he told me that, having a special paper to prepare, he went to a store and bought a pound of candles, which he placed about his room, on all sorts of extemporaneous candlesticks; "for light," he said, "is a most powerful tonic."

These anecdotes will serve to recall similar ones of noted men, and many of you, doubtless, were this an experience meeting, could easily occupy the balance of the evening in delightful recollections of what each has found best to stimulate him to renewed intellectual activity; and I dare say that many of you would unite with me in declaring that membership in this society has been one of the most helpful and stimulating influences.

We really have much to be proud of in the history and membership of the Philosophical Society of Washington. I should, indeed consider myself remiss in the duties imposed upon me by the subject selected did I not refer at least to the eminent part this society, through its members, has taken in bringing about the wonderful appreciation of scientific work and scientific methods we are to-day witnessing in our country. There have been several notable addresses by past presidents that might advantageously have been reviewed in connection with our topic. But we lack the time.

I cannot refrain, however, from quoting once more from Henry's address, already referred to, which I hope you may be induced to read in its entirety:

> Man is a sympathetic being, and no incentive to mental exertion is more powerful than that which springs from a desire for the approbation of his fellowmen; besides this, frequent interchange of ideas and appreciative encouragement are almost essential to the successful prosecution of labors requiring profound thought and continued mental exertion. . . .
>
> It is an essential feature of a scientific society that every communication presented to it should be subject to free critical discussion. Such discussion not only enlivens the proceedings, but is generally instructive, frequently eliciting facts which, though insignificant when isolated, when brought together mutually illustrate each other and lead ultimately to important conclusions.

CONCLUSION

My address began with statements revealing the necessity of keeping our minds ever open and free for the careful weighing and the unbiased reception of the facts observed and discovered. Throughout I have attempted to lay chief stress upon the mental and human elements involved in the topic. I can not do better in closing than to quote you a sentence from a letter[5] which the great mathematical physicist, James Clerk Maxwell, wrote to Herbert Spencer on a subject of controversy in the latter's "First Principles," *viz.:*

> It is very seldom that any man who tries to form a system can prevent his system from forming around him, and closing him in before he is forty. Hence the wisdom of putting in some ingredient to check crystallization and keep the system in a colloidal condition.

Let our watchword therefore be: *ever to keep our systems—our theories—in a colloidal condition!*

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[5] "Life and Letters of Herbert Spencer," by David Duncan, Vol. II., p. 163.

Dr. David Starr Jordan,
President of Leland Stanford Junior University and President-elect of the American Association for the Advancement of Science.

THE PROGRESS OF SCIENCE

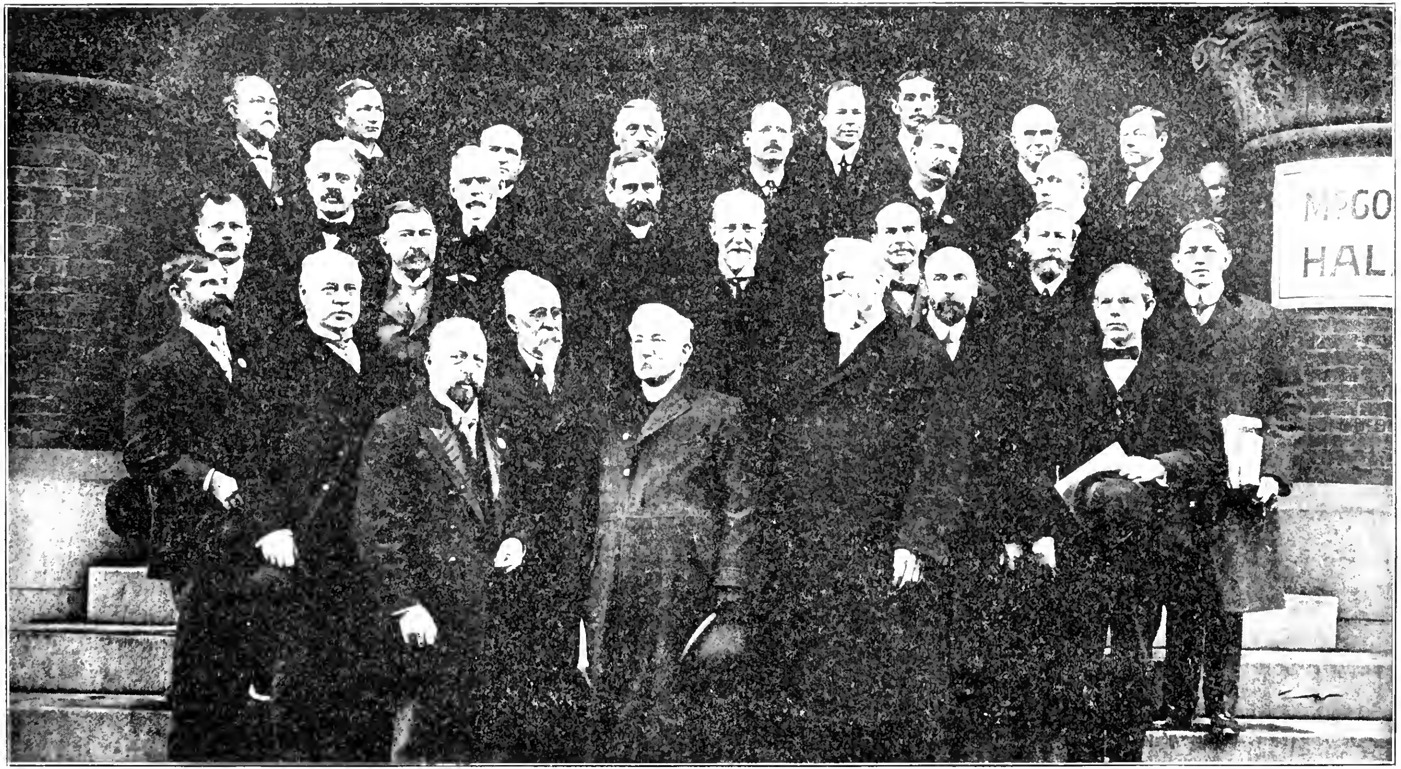
THE SCIENTIFIC MEETINGS AT BALTIMORE

THE meetings of the American Association for the Advancement of Science and the affiliated national scientific societies held at the Johns Hopkins University during convocation week brought together more than two thousand scientific men and their programs contained the titles of more than one thousand scientific papers. Such a gathering has not occurred elsewhere or hitherto, and it is encouraging to see demonstrated in this public way the fact that this country is now taking the place in scientific research warranted by its population and its wealth. The meeting is not only an exhibition of what has been accomplished; it is also a stimulus in further efforts. The scientific men who come together from all parts of the country to present and discuss the results of the year's work return to their institutions with more knowledge and renewed zeal. It would be worth the while for each of our thousand colleges—and the smaller and more remote they are the more worth the while—to pay the expenses of delegates to a meeting of this kind. This would be no less useful or profitable than to supply books or apparatus. Dartmouth College set this year a precedent, making an appropriation of $300 to send nine representatives to the meeting.

The arrangements by the local committee worked so smoothly and the meeting places of the groups were so separated that it was difficult to realize fully the magnitude of the meeting except by reference to the program. In it one found some seventy pages devoted to a mere list of the papers to be presented and a great array of general meetings, public lectures, dinners, smokers, etc. From this vast mass of material only a few events can be selected for mention.

At the opening meeting on the morning of December 28, the retiring president, Dr. E. L. Nichols, professor of physics at Cornell University, introduced the president of the meeting, Dr. T. C. Chamberlin, professor of geology at the University of Chicago, and the association was welcomed to Baltimore by the mayor of the city, by Dr. Ira Remsen, president of the Johns Hopkins University, who presided at the first convocation week meeting in Washington six years ago, and by Dr. William H. Welch, chairman of the local committee and professor of pathology in the Johns Hopkins University, who presided at the New York meeting two years ago.

In the evening the retiring president gave his address, which was an admirable survey of the place of science in modern civilization and an impressive plea for more research work and greater freedom in our universities. All the vice-presidential addresses before the sections of the association and the presidential addresses before the special societies maintained high scientific standards, and some of them were of broad general interest. Among the lectures may perhaps be selected for mention the addresses by Mr. G. K. Gilbert, of the U. S. Geological Survey, on earthquake forecasts, which had a sad and dramatic timeliness; by Major Squier, U.S.A., on the remarkable recent progress in navigating the air by means of dirigible balloons and aeroplanes; by Mr. Bryan, on Mt. Kilauea, whose address was beautifully illustrated and of special interest in view



MEMBERS OF THE COUNCIL OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

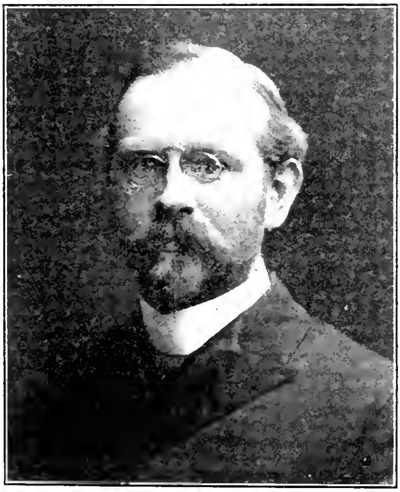
At the front are: Dr. Wm. H. Welch, Chairman of the Local Committee and Past President of the Association; Dr. L. O. Howard, Permanent Secretary; Professor Charles E. Bessey, retiring Vice-president for the Section of Botany; President R. S. Woodward, Treasurer and Past President; and Professor T. C. Chamberlin, President for the Baltimore meeting.

of the probable meeting of the association in Honolulu eighteen months hence; by Professor Wilson, of Columbia University, describing the classic researches made by him and others on the determination and heredity of sex; by Dr. Brown, U. S. Commissioner of Education, who spoke with authority on world standards of education; by Professor Penck, of Berlin, eminent as a geologist and geographer, who lectured on man, climate and soil, and by Professor Poulton, of Oxford, the leading authority on natural selection, whose subject was mimicry in the butterflies of North America.

Dr. Louis Kahlenberg,
Professor of Physical Chemistry in the University of Wisconsin, Vice-president for the Section of Chemistry.

In addition to the great number of discussions and special sessions, two memorial meetings were of striking significance. The former students and colleagues of William Keith Brooks, professor at the Johns Hopkins University from its establishment in 1876 to his death, two months ago, met to do honor to his memory. No fewer than sixty joined in a dinner on the last day of the old year, and their numbers and standing not less than their words bore witness to the great influence exerted by Brooks on the development of the biological sciences throughout the country. The last day of the meeting and the first day of the new year was devoted to a Darwin

Dr. C. J. Keyser.
Adrian Professor of Mathematics in Columbia University, Vice-president for the Section of Mathematics and Astronomy.



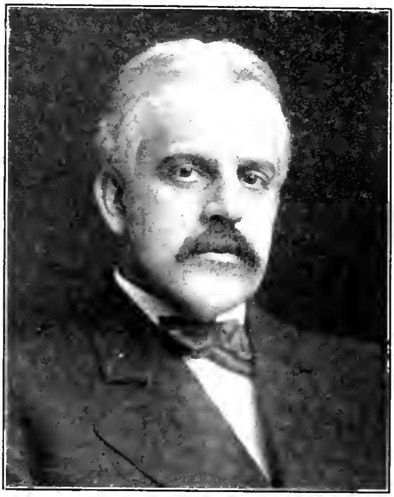
Dr. Carl E. Guthe.
Professor of Physics in the University of Iowa, Vice-president for the Section of Physics.

Dr. C. Judson Herrick.
Professor of Neurology in the University of Chicago and Vice-president of the Section of Zoology.

memorial, celebrating the hundredth anniversary of his birth, which occurs on February 12, and the fiftieth anniversary of the publication of the origin of species. Professor Poulton, who came from England to take part, gave a vivid account of Darwin's work and influence. He was followed by a number of leading American investigators of problems of organic evolution whose papers gave an excellent survey of present conditions, showing both the dependence of modern biological science on Darwin's work and the new problems which have now come to the front.

Dr. William H. Howell.
Professor of Physiology in the Johns Hopkins University and Vice-president for the Section of Physiology and Experimental Medicine.

Dr. David Starr Jordan, president of Stanford University, eminent as an ichthyologist and as a student of a wide range of evolutionary problems and equally for his services to education and civilization, was elected president for the meeting to be held next year in Boston. The vice-presidents of the Baltimore meeting were worthily succeeded by a group of men who represent the best scientific work now being done in this country. They are: *Mathematics and Astronomy*—Professor Ernest W. Brown, Yale University. *Physics*—Dr. L. A. Bauer, Carnegie Institution, Washington, D. C. *Chemistry*—Professor William McPherson, son, Ohio State University. *Mechan-*



Dr. Herbert Maule Richards.
Professor of Botany in Barnard College, Columbia University, and Vice-president for the Section of Botany.

Dr. R. S. Woodworth,
Adjunct Professor of Psychology in Columbia University and Vice-president of the Section of Anthropology and Psychology.

ical Science and Engineering—Dr. J. F. Hayford, U. S. Coast and Geodetic Survey. *Geology and Geography*—Dr. R. W. Brock, director of the Canadian Geological Survey. *Zoology*—Professor William E. Ritter, University of California. *Botany*—Professor D. P. Penhallow, McGill University. *Anthropology and Psychology*—Dr. William H. Holmes, Bureau of American Ethnology. *Social and Economic Science*—President Carroll D. Wright, Clark College. *Physiology and Experimental Medicine*—Professor Charles S. Minot, Harvard Medical School. *Education*—Dr. J. E. Russell, dean of Teachers College, Columbia University.

George F. Swain,
Professor of Civil Engineering in the Massachusetts Institute of Technology and Vice-president for the Section of Mechanical Science and Engineering.

THE REPORT OF THE SECRETARY OF AGRICULTURE

Secretary Wilson's annual report to the president is a striking document, almost bewildering in the range and magnitude of the subjects of which it treats. It is not easy to think in billions of dollars and realize what it means to say that the value of our farm products in 1908 was $7,770,000,000. This is about three hundred million dollars above the value in 1907 and three billion dollars above the value in 1899. The increase is, however, in part due to higher prices, as well as to larger production, and in so far as all prices have risen, even the farmers do not profit. But their wealth has increased greatly in recent years. The six million farms of the country are valued with their buildings and stock at twenty-eight billion dollars. While individual bank deposits have increased 12 per cent. in New York State, they have increased 285 per cent. in Iowa and 334 per cent. in Kansas. The farms of Kansas, mortgaged to the east twelve years ago, now send their profits to be invested in New York. The exports of agricultural products last year were valued at over one billion dollars, representing a great increase in the wealth of the country, though it is to be feared that it in part means the sale of the fertility of the soil. Indian corn is valued at about one third of all farm crops;

wheat, hay and cotton at more than one third and the smaller crops at nearly one third. The annual value of animal products is approximating three billion dollars.

The work of the Department of Agriculture is commensurate with this vast production of the farms. When Secretary Wilson assumed charge eleven years ago, there were less than 2,500 persons employed. There are now more than 10,000, and of these more than 2,600 may be classified as scientific men. The bureau that has had the most remarkable growth is the Forest Service, which has increased from 14 persons to 3,753. It administers an area of national forests amounting to 168,000,000 acres, which paid last year into the national treasury $1,800,000 in receipts. The income of the agricultural colleges was five million dollars in 1897 and fifteen million dollars in 1908. There was one agricultural high school in the former year and no normal school taught agriculture. There are now fifty-five agricultural high schools and one hundred and fifteen normal schools at which agriculture is taught. The Department of Agriculture distributed last year nearly seventeen million publications. The more these are read the better it is, not only for the farmers of the country, but for all the people.

SCIENTIFIC ITEMS

We record with regret the deaths of George Washington Hough, professor of astronomy at Northwestern University and director of the Dearborn Observatory, and of Thomas Gray, professor of engineering at the Rose Polytechnic Institute.

Presiding officers of societies meeting at Baltimore were elected as follows: The American Society of Naturalists, Professor T. H. Morgan, of Columbia University; The Geological Society of America, Mr. G. K. Gilbert, of the U. S. Geological Survey, for the second time, he having held this office in 1892; The American Chemical Society, Dr. W. R. Whitney, director of the Research Laboratories of the General Electric Company, at Schenectady; The American Zoological Society, Professor Herbert E. Jennings, of the Johns Hopkins University; The American Anthropological Association, Dr. W. H. Holmes, chief of the Bureau of American Ethnology; The American Psychological Association, Professor Charles H. Judd, professor of psychology at Yale University and director-elect of the School of Education in the University of Chicago; The American Philosophical Association, Professor J. G. Hibben, of Princeton University.

Professor T. C. Chamberlin, after presiding at the Baltimore meeting of the American Association, left for San Francisco on his way to China, where he will study the geology of the country with special reference to its influence on social and educational conditions, as a member of a commission sent by the University of Chicago.

THE
POPULAR SCIENCE
MONTHLY.

MARCH, 1909

THE ELECTRIC OPERATION OF STEAM RAILWAYS

By Professor J. B. WHITEHEAD
THE JOHNS HOPKINS UNIVERSITY

THE possibility of operating all classes of steam railway service by electricity has been demonstrated beyond question. Heavier trains may be hauled at higher speeds and with greater comfort to passengers, and electric locomotives may be built which surpass in power any steam locomotive which may be constructed. Two of the most important railway systems entering New York city are now operated entirely by electricity for distances between twenty and thirty miles from Grand Central Station. The Pennsylvania Railroad Company has recently closed contracts to the extent of $5,000,000 for the electric operation of its tracks between Newark, N. J., through the Hudson and East River tunnels, to Jamaica, L. I., where it will join the tracks of the Long Island Railroad, which for some time has been operated electrically.

The total steam railway mileage in this country aggregates about 220,000 miles of line but notwithstanding the important projects mentioned above, and others of less note, it remains a fact that only about 1,000 miles of railroad, formerly operated by steam, have been transformed to the use of electricity as motive power. The question then arises as to what conditions have started the present development and as to whether this beginning will extend itself in general degree to the large trunk line systems of the country. It is not sufficient for the engineer of to-day to demonstrate the physical possibilities of a project, but he must go further, and justify it on the grounds of business advisability and economy. If, then, it be asked why have steam railroads begun to substitute electricity as motive power, the answer is to be found in two broad reasons. The first of these is, that in some instances the use of electricity is the only possible way of handling the traffic. The second reason is the invariable one, in this commercial age, for all engineering enterprise—that it pays.

The development of the engineering methods by which the electrical operation of railways has been made possible is largely due to the first of the reasons mentioned above. Beginning with the electrification of the Mt. Royal Tunnel of the B. & O. Railroad, in 1896, there have been an increasing number of tunnel and terminal projects which have made use of the possibilities of electric operation in the way of increased traffic and freedom from smoke and gases of combustion. One conspicuous instance, the Grand Central Terminal in New York city, illustrates the typical limitations of tunnels and terminals which have rendered electric operation necessary. In 1903, an act of the New York Legislature was passed providing for the operation before July 1, 1908, of all trains into Grand Central Station by some form of motive power not involving the combustion of fuel in the motive units. This action was aimed directly at the elimination of smoke and gases in the tunnels leading to the terminal. The results of the adoption of electricity have in this respect entirely justified expectations. Passengers may now occupy observation platforms in passing through these tunnels which were formerly notorious for their danger and discomfort.

There was, however, an additional reason why it was necessary to adopt a motive power other than steam in the New York terminals. Traffic into the Grand Central Station is limited by the number of tracks in the tunnels. The minimum three-minute headway between trains operated by steam fixed the maximum traffic at forty trains per hour each way. The capacity of the terminal with this limitation of service was taxed to its utmost and some relief for the increasing traffic was imperative. Owing to the improved conditions of electric operation, trains may be run on a two-minute headway or less, thus increasing the station capacity by more than fifty per cent. The conditions in the New York tunnels are typical and other conspicuous instances of similar installations are those of the B. & O., at Baltimore, the St. Clair tunnel of the Grand Trunk Railway and a three-mile tunnel on grade on the Great Northern Railway. The Illinois Central Railroad is about to electrify 325 miles of track, comprising the approaches to its Chicago terminals.

The elevated lines of New York city are an additional instance of the necessity of adopting some other system than steam in order to increase the capacity for traffic. The continued growth of the population of New York city has far surpassed that of the traffic facilities for transportation within the city. As measures for relief the elevated and surface lines were equipped with electricity and in addition the subway system was constructed. Within three years following the adoption of electricity, the capacity of the elevated lines in car-miles per day was increased 33⅓ per cent. and this in spite of the facts that the subway system had inaugurated during this time a service furnishing over 75 per cent. that of the steam elevated and that the surface lines showed little or no decrease. During the two years ending 1906 the increase in passengers on all the lines of New York city numbered more than 114,000,000, which is about 75 per cent. of the ultimate capacity of the subway system. In order to handle this continuously increasing demand it has now become necessary to consider the construction of additional subways.

Returning to the second of the reasons given for changing to electricity, the general statement that it will pay to electrify a steam railroad may not be made without important qualifications. It is admittedly true for the majority of steam roads of any considerable size and density of traffic that the operating expense would be substantially reduced by electric operation. Figures showing that this saving, together with the returns from increased business, is sufficient to offset the interest charges on the necessary capital are still few. Such figures have, nevertheless, been given for existing roads on which the transfer to electricity has been made. On the other hand, on railroads operating light trains and comparatively infrequent traffic, it is at once evident that there would be little if any saving in operating expense in changing the motive power. Much of the economy possible under electric operation results from the combination of all the locomotive boilers and engines into a central power plant. It is obvious that when the number of such locomotives is small that the cost of the power plant and the motor equipments may far outweigh the economies obtained. There is, however, an intermediate class of road, many instances of which have been equipped electrically, in which the saving in operating expense, together with the usual increase of business following the electric installation, are looked to for a reasonable return on the capital invested. The enormous amount of capital represented by the steam equipments of existing railroads, which can not be applied to the new equipment, is the most serious obstacle to the general adoption of electricity as motive power. It will only pay to electrify in those cases where the economies in operation and the increase in business will outweigh the charges on the new capital necessary.

The public will invariably drift to an electric rather than a steam route between given points. Moreover, when a steam road is paralleled by electric service, not only does the latter take the bulk of the traffic, but the traffic itself increases in volume. Further, when a sparsely settled section is penetrated by an electric road, population and consequent business follow promptly. These facts are now matters of common observation. One extreme example will indicate the lengths to which these facts may go. A steam road in the middle west was paralleled by an electric line; the latter took away over fifty per cent. of the steam traffic and increased the total traffic fifteen times the original amount within seven years. If we look for the reasons for such advantages in absorbing and promoting traffic we realize that electric travel is faster, more frequent and more comfortable. It provides freedom from smoke, better ventilation, easy regulation of light and heat and in fact travel in many instances is actually a pleasure.

While the public is appealed to as cited above, the operating and transportation departments of the railroad are equally appealed to by the methods afforded under electric operation for handling the resulting increase in business. Present day steam service may be divided into three broad classes: (1) Suburban and terminal; (2) long haul passenger and express and (3) freight traffic. The advantages of electricity as motive power in all three of these classes of service are found in the possibilities of obtaining more mileage and hauling capacity from the equipment, the operation of more trains on the line at one time and better operating conditions and consequent reliability.

Figures have already been given showing the increased train capacity of the several electric installations in and about New York city and many other similar instances might be cited. These results are largely due to the fact that an electric locomotive or train operates at a higher schedule speed than is possible under steam. The elapsed time of a suburban train between stops depends principally on the rapidity with which it attains its maximum speed. The rate at which it reaches this speed, that is, the acceleration, depends on the value of the pull exerted by the motive power. During the period of starting the greatest draw-bar pull is required, since during this time the inertia of the mass of the train must be overcome. After reaching a maximum speed the only forces to be overcome are those of frictional resistance of the track and the air. In a steam locomotive the greatest draw-bar pull being required at starting, steam is admitted to the cylinders throughout the full length of the stroke. The demand on the boiler per revolution is, therefore, greatest at this time. No locomotive can, on the average, exert a greater pull than 25 per cent. of the weight carried by its own driving wheels, for beyond this figure the wheels will slip on the track. The boiler capacity, therefore, is designed to give no more steam than that demanded by this value of the pull at starting. A steam train, therefore, does not utilize the weight of its own cars as a means of increasing its grip on the rails. In a multiple unit electric train, motors are placed on each car, thus utilizing the weight of the entire train for frictional adhesion to the rail. By electric control of the motor switches all the motors may be operated simultaneously by one man at the head of the train. By this system the draw-bar pull per ton of train may be increased from 2.5 to 4.5 times that for steam and the rate of acceleration is only limited by the comfort of the passengers. As a direct result of this the schedule speed is increased, the headway between trains is reduced and more trains may be operated on the line. By the use of electric locomotives in terminals for switching service great economies are effected. Since the electric locomotive operates in either direction and takes its entire power supply from the trolley or third rail, much useless mileage of locomotives in going to and from the turn-table, the water-tank and the coal-chute is avoided. The New York Central has already reported as a result of tests a net saving of 21 per cent. on the cost of switching service and 16 per cent. in the ton mileage of switching locomotives.

For long-haul passenger and express service rapid acceleration is not so important, but the maximum speed becomes the determining factor in a fast schedule. For any type of motive power the draw-bar pull is greatest at starting and falls to lower and lower values as maximum speed is approached. Consequently, for this class of service, large initial effort is not so important as large effort at high speed. In this respect the electric motor has a great advantage over the steam engine. Since the boiler of the steam locomotive is proportioned to the maximum demand which it can generate at starting, corresponding to the grip which it has on the rails, at higher speeds the steam must be cut off from the cylinders at a less and less fraction of full stroke, for otherwise the boiler can not supply steam fast enough and still maintain its pressure; thus the total tractive effort, which depends on the proportion of a revolution during which steam is admitted to the cylinders, is reduced as the speed increases. While the tractive effort of the electric motor also decreases somewhat with the speed it does not do so nearly as rapidly as that of the steam locomotive. As a consequence, a given weight of train can be handled faster by electricity than by steam or a heavier train may be hauled at a given maximum speed. Again, the safe limits of speed are much higher in electric operation. The rotative effort is uniform in a motor, while that of a locomotive is intermittent and accomplished through the medium of heavy reciprocating parts. The moving mass of these parts as the speed increases tends to lift the locomotive from the track and pounds the rails with a blow which in many instances has been sufficient to cause derailments. The limiting speed of steam trains is about 80 or 90 miles per hour, while speeds of 130 miles per hour have been reached in tests on electric trains.

The advantages of electricity for freight traffic are most apparent on long single track lines with heavy grades and mixed traffic. The length of the freight train of to-day is limited by the draw-bar pull of the locomotive which is in turn dependent on the locomotive weight, and by the schedule speed. Speaking generally, longer trains and hence fewer trains on the line at one time, are to be had only at great sacrifice of speed. The longest freight trains weigh from 2,000 to 3,000 tons and are only operable on level track. On reaching mountain grades, such trains have to be broken into two or three parts, which, therefore, on single-track roads increase the number of passing points and subsequent delays, thus rapidly shortening the headway between trains and filling the line to its capacity. Schedule speeds on such grades now average about ten miles per hour. The operation of two or more locomotives in a train is not satisfactory, owing to the impossibility of securing simultaneous cooperation of the several motive units. As already stated the tractive effort at high speeds is much greater for the motor than for the steam locomotive; hence, in the case of electric operation, the limiting weight of the train on grade is higher, also the schedule speed may be largely increased by the use of double or triple headers. This method of operation is perfectly possible under electricity by the system of multiple control, already mentioned, and the length of a train is limited only by the strength of the draft gear. This limit would disappear if all freight cars could be equipped with a simple standard cable, enabling the placing of an electric locomotive in the middle or at the end of a train. This cable would be necessary to secure the simultaneous operation of the several locomotives.

A few comparative figures bearing out the above facts of the possible methods of increasing railway business are not without interest. A typical western freight locomotive, weighing with its tender 165 tons, can develop continuously a draw-bar pull of 25,600 pounds, up to a speed of 15 miles per hour. An electric locomotive, weighing 100 tons, can develop this value of pull, up to a speed of 37 miles per hour. Another similar type of electric locomotive gives 56,800 pounds, up to 23 miles per hour, and still another 8-motor type can develop 113,600 pounds draw-bar pull up to a speed of 23 miles per hour.

A late type of Mallet compound locomotive, weighing 300 tons, can develop continuously 2,180 horse power at its driving wheels. A New York Central electric locomotive can do the same and weighs only one third as much. The cost of each locomotive is about the same. It may be noted that 200 ton-miles are saved in every locomotive mile if the electric locomotive is used instead of the steam locomotive. At 40 cents per locomotive mile and 100 miles per day the saving is $40 per day or about $15,000 per year. The saving on this account alone would in two years pay for the electric locomotive. Another type of Mallet locomotive, weighing with its tender 250 tons, can haul a train weighing 330 tons up a 2.2 per cent. grade at 15 miles per hour. A 100-ton electric locomotive can haul a train of 800 tons under the same conditions. The total train weights are thus 580 and 900 tons and the electric locomotive weighs 100 tons less than the steam locomotive, resulting in the consequent saving in the ton mileage of dead weight.

The operating conditions and the reliability of service are improved in all classes of traffic by the substitution of electricity. The construction of the electric locomotive is far simpler. The steam locomotive comprises fire box, boiler, steam engine and facilities for handling coal and water. The electric locomotive, on the contrary, consists only of the electric substitute for the engine and this substitute has no reciprocating parts. There is consequently less wear and tear and less likelihood of derailment and broken rail. The fire box and boiler are absent as sources of danger in a collision, as are also apparatus for steam or fire heating and oil or gas lighting. Signals are clearer in the absence of smoke and automatic signals are possible, though as yet they are little used. The control of power to trains in sections or blocks is also possible. The number of car miles per train-minute of delay has been nearly doubled on the elevated lines of New York since the electrical operation was inaugurated. Less time is required for clearing and despatching trains, water and coal stops are obviated and less attention is required for light and heat. The electric locomotive is always ready, requiring no time for firing.

As against these several advantages in operating conditions and reliability, there are several disadvantages. The supply of power to all trains from one power house is objectionable from the standpoint that an accident at the power house may stop all trains. Whatever may be said of the steam locomotive in its comparison with the electric motor, the locomotive is self-contained. This danger under electrical operation is minimized by a thorough subdivision of all the power house apparatus. This method of subdivision, however, is not so readily possible in the transmission and conducting systems leading power to the trains and accidents to this portion of the equipment constitute one of the most serious menaces to the continuous operation of an electric railroad. The presence of the third rail or trolley and the transmission line throughout the right of way is in itself a certain source of danger. In a collision the danger of a fire from a third rail in some measure offsets the similar danger from a locomotive fire box. The danger from this source, however, has been overestimated, and the danger of shock from a high voltage trolley is practically eliminated by the modern methods of suspension. These methods consist in supplementing the actual trolley conductor with one or more steel cables for increasing the tensile strength of the overhead construction. The thorough grounding or connecting to the rail of all the supports of the trolley wire ensures that even in the unlikely instance of the breaking of the overhead construction the wire will have no voltage when it reaches the ground. So reliable has this method of suspension come to be regarded that it is now often used for crossings of telegraph, telephone and transmission wires in place of the usual cradle or network of wires stretched between the two lines. The values of voltage now advocated for railway and transmission work have caused considerable criticism and opposition. This is probably due in large measure to the long standing figure of 600 volts for trolley service; this figure, however, is fixed by the character of the direct current motor and not by any consideration of possible danger from shock. A further source of disturbance by electrical operation is the interference by electrostatic and electromagnetic induction between the transmission conductors and the telegraph and telephone lines in the vicinity. Methods have been developed, however, and are at present in use by which such disturbances are prevented at slight cost.

A decrease in the operating expenses has already been stated as one of the means by which electric operation may be made to pay. The operating expenses of an average steam railroad may be roughly divided as follows: Maintenance of way 21 per cent., maintenance of equipment 19 per cent., conducting transportation 56 per cent., general expenses 4 per cent. Considering these items under electric operation the greatest saving is effected in the item of conducting transportation, which includes the cost of coal. The steam locomotive consists of a boiler and engine. For obvious reasons neither is as efficient as the same apparatus of a stationary type. The same amount of coal in a locomotive boiler will evaporate only about two thirds as much water as in a stationary boiler. The average steam consumption of a good locomotive engine is about 30 pounds of steam per horse power hour developed; turbo-generators are now guaranteed for a consumption of only 15 pounds of steam per electrical horse power at the switchboard. As offsetting these marked advantages it is necessary to consider the electrical losses in the transmission system and in the motor equipments. Speaking roughly, 75 per cent. of the electrical energy supplied by the switchboard is available at the wheels of an electric train for tractive effort. These figures indicate that an electric locomotive requires less than one half the amount of coal used by the steam locomotive giving the same horse power output. Further than this, it has been estimated that for every hour that a locomotive is standing idle, with steam up, 400 pounds of coal are burned. The excess of useless mileage and the excess ton mileage owing to the greater weight of the steam locomotive have already been noted, and are also causes for excess coal consumption. As opposed to these, there is the light load coal consumption of the power station. The final value of the balance in coal saving will depend on the proportion of time in which the power station operates to its full capacity. Based on careful comparative tests of steam and electric locomotives the engineers of one of the large installations already mentioned have announced that the electrical operation of the former steam service is being handled with the consumption of only 60 per cent. of the amount of coal, resulting in a saving of nearly $350,000 per year. Figures have been published showing that the Manhattan Railway under steam operation secured about 1.5 ton miles to a pound of coal; under electric operation this figure has increased to 3.85. These and other careful estimates indicate that in the general electrification of through railway lines a saving of 50 per cent. in coal consumption may be effected. It is to be noted, however, that the cost of fuel alone is only about 12 per cent. of the total cost of operation; therefore, a saving in this respect would be only 6 per cent. of the total operating expense. In the kindred items of firemen, roundhouse men and other expense peculiar to the steam locomotive a further saving of about 5 per cent. is possible. It is interesting in this connection to consider the effect of this fuel saving on the total coal supply of the country. The fuel consumption of all the locomotives in this country in 1905 was about 52,000,000 tons, which was about one eighth of the total coal production of that year. The total coal consumption, therefore, would be reduced by about 7 per cent. if all the railways in the country were electrified. This does not appear to be a very important reason why railways should electrify; but with trans-Atlantic liners burning 5,000 tons of coal per voyage and the end of the coal supply of the state of Ohio in sight within 25 years, any influence tending to check coal consumption must soon assume importance.

The repairs to steam locomotives amount to about 8 per cent. of the total operating expense. The repairs to an electric locomotive amount to far less. The greater simplicity of the electric locomotive has already been noted. There are now available plentiful data based on experience indicating that the above figure of 8 per cent. may be reduced to the neighborhood of 2 per cent. An additional saving in the maintenance of track and other less striking items offsets the repairs to track bonding and overhead construction and leaves an additional saving in favor of electric operation of about 3 per cent. The aggregate of the above economies in operating expense amounts to 20 per cent., which should be readily available by any of the large railway systems in the transformation to the electric method of operation.

Considering further the several pioneer installations of electric service, we find that they differ materially in their characteristics and there are several so-called systems at present available. The early development of the electric railway for operation in cities was entirely dependent on the use of the direct current motor as the only motor available. This motor had been developed in spite of the fact that the earliest electromagnetic generators were of the alternating current type. The value of alternating currents was not appreciated, however, as the principles of transformation and their value for transmission were not understood. The high degree of perfection to which the direct-current motor has been developed naturally led to its use for railways as city lines were extended, and this tendency has resulted in the enormous mileage of suburban and interurban electric railways. This tendency was aided by the development of the rotary converter which permitted the transmission of power by alternating currents and its conversion to direct current for supplying the trains. The direct current motor operates at about 600 volts and thus fixes the value of the voltage on the trolley or third rail. The voltage being fixed, the total energy at a car is proportional to the current. Thus, for light cars and infrequent traffic, the loss in the trolley and feed wires, due to the passage of current delivering energy to the car, is sufficiently small to allow operation at comparatively long distances from the point of generation. With increasing size of cars or trains the points of supply must be brought nearer together and be made of greater capacity. In the case of the New York Central installation, the average distance between such stations is four miles. Each of these sub-stations contains transformers for reducing the voltage from the transmission line and rotary converters for changing the alternating to direct current. The amount of current taken by a train on this system may go to very large values and this necessitates large trolley and feeding conductors when the traffic increases in volume. Under this system the feeding conductor may be either trolley or third rail and the collecting device, the trolley wheel or third rail shoe. The latter must be used when the currents are of large value.

With increasing length of line the cost of sub-stations and feeders in the direct current system becomes prohibitive. This has lead to the development of alternating current systems, in which the energy is generated, transmitted and delivered to the car at voltages as high as 15,000, with consequent reduction in values of the necessary current. Theoretically, the reduction in the size of conductors necessary to carry the current is inversely proportional to the square of the voltage. While certain characteristics of the alternating current system reduce this theoretical value quite materially, the gain in this respect is nevertheless enormous, and the distance between feeding points increases to between thirty and fifty miles, depending on the density of the traffic. The trolley wire alone is often the only feeding conductor required. Further, the apparatus in the sub-stations in these systems comprises stationary transformers only which require no attendance. Two conspicuous alternating current systems for railway operation have been developed. The single phase system, which has been almost the only alternating current system used in this country, and the three-phase system, which has met with some favor in Europe.

The single-phase motor has the same characteristics and operates exactly as the direct current motor and may in fact be operated by direct current—a fact which constitutes one of its greatest advantages. It is, however, heavier for the same output and since it, too, operates at low voltage, a stationary transformer is required on the car or locomotive to reduce the high trolley voltage to the value required. This necessitates a heavier and more expensive motor equipment than the direct current system and acts as an offset to the saving effected in feeding conductors and sub-stations. In this system the feeding conductor is the overhead trolley with catenary suspension and the collecting device is the sliding trolley or pantagraph which is necessary for very high speed and permissible by reason of the low values of current required.

The three-phase system owes its principal value to the fact that the speed variation of the motor is very small throughout its full range of tractive effort. As already stated, the tractive effort of the direct-current and single-phase motors falls off with increasing speed, though not so rapidly as that of the steam locomotive. Owing to this advantage, the three-phase locomotive can maintain its high speed independently of the grade. It operates without transformers on the car with trolley voltages up to 5,000 and in coasting it returns power to the line automatically, its motors acting as generators. It is, however, heavy per unit of output and the system requires two trolley wires and is not adapted to operation on the direct-current installations to be found in many terminals. It has been adopted for one installation in this country in which it is desired to increase the schedule speed on a long mountain division.

In this country the best engineering opinion seems to have united in thinking that the single-phase system is the one best adapted for future application to steam railways. This system is as yet only four years old, yet there are at present over 1,000 miles of railways in the United States operating under it and in this aggregate there are at least five railroads formerly operated by steam. The system has proved most successful in operation, although the first six months' operation of the New York, New Haven & Hartford Railroad have developed so many unforeseen troubles, when applied to such a large enterprise, as to bring upon it much adverse criticism. On the other hand, the high degree of perfection to which the direct-current system has been brought, the greater capacity of the motors of this system and the enormous mileage already installed in tunnels and terminals have resulted in a strong advocacy of this system. Speaking generally for motors of equal weight, that of the direct-current system has 25 per cent. more capacity than that of the alternating-current system. The equipment of a high speed interuban car having four motors of approximately 100-horse-power capacity, will weigh under direct current system 22,500 pounds and under the alternating system 32,000 pounds, or nearly 50 per cent. excess over the direct-current equipment. For the entire car, however, the excess weight would be only about 12 per cent. The excess in cost would be about 35 per cent. In the case of locomotives the excess weight of the alternating-current equipment is even greater. The New York, New Haven & Hartford alternating locomotive has about the same weight as the New York Central direct-current locomotive, but if compared on the basis of maximum tractive effort the former weighs twice as much. The two locomotives are, however, designed for different service and the comparison is much more favorable to the alternating-current system if based on the continuous capacity. The cost of each of these locomotives is about the same.

Taking a broad view of the situation at present, we find that the direct-current system is already installed and continues to be favored for dense, short-haul traffic, such as is found in city terminals and tunnels, and short suburban service. This is largely due to the greater familiarity with the direct-current motor, to its greater capacity and less cost. It is admitted, however, that this system will not do for through traffic over long distance. The single-phase system possesses marked advantages for long haul, express and passenger service on account of the great saving effected in line conductors and sub-stations. It has the great additional advantage that it can operate on direct currents also and may, therefore, enter terminals already equipped with direct current. There is every indication that the operation of steam railways by electricity will be rapidly extended within the next few years. It appears probable that the single-phase, high-voltage, alternating-current trolley will be used and that for some time direct current will continue to be used in terminals. The tendency, however, will be to abandon direct current in terminals, substituting the high voltage trolley throughout.

The process of change to electricity, however, must necessarily be gradual. The necessary capital investment must be provided for and this will probably be accomplished in any large instance by doing the work piece-meal and charging the cost to renewals. Methods for handling freight traffic have not yet been thoroughly developed. Much freight hauling is done by electricity, but before the bulk of traffic of a through line can be handled some method of multiple operation must be devised for freight trains and the work must be experimented upon by applying the methods at present indicated, to some large project. The standardization of electric railway apparatus is one of the greatest necessities of the present situation. No extensive system would care to operate its trains without the possibility of the exchange of cars with neighboring systems and until railway engineers are agreed as to the fundamental questions of frequency and methods of train control it is probable that no large project will be put in hand. A further opposition to be met is the mass of present-day, steam-railway methods and prejudices. The steam railway has a long history and each system has its highly-trained corps of operating engineers. Electrical operation introduces many new points of view, old dangers disappear and new precautions have to be taken. Besides these matters, there are various less important disturbances to steam practise which will have to be provided for, among the most serious of which are the clearances of the third rail and trolley at crossings and at overhead structures; the clearances on draw-bridges and the methods of leading currents through such bridges; new splice bars to accommodate rail bonds and the telltale for notifying a brakeman on top of the car of a low bridge ahead. It seems probable that the next step in this development will be the progressive equipment of a complete system involving through traffic over long distances, with its attendant feeder and branch lines. When such a system is once installed and the minor difficulties above enumerated developed and overcome, a rapid application of electricity for steam operation will follow.

THE INFLUENCE OF RADIUM RAYS ON A FEW LIFE PROCESSES OF PLANTS[1]

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THE purpose of the present paper is to present in non-technical form some of the more striking results embodied in the author's memoir on "Effects of the Rays of Radium on Plants."[2]

It is now well known that radioactivity was discovered by Henri Becquerel in 1896. Earlier in this same year Niewenglowski had found that several substances, after being exposed to sunlight, gave off a new kind of rays that could penetrate matter opaque to ordinary light. Following up this work, Becquerel found that the salts of uranium gave off such rays, even when not exposed to sunlight. Uranium, he said, manifests a kind of "invisible phosphorescence." It was Madame Curie who, in 1898, proposed the term "radioactive" for substances possessing this property. In 1898, also, M. and Mme. Curie and Bémont announced the discovery of a new substance *fortement radio-active,* contained in pitchblende. In a moment of inspiration they named it *radium.*

The discovery of radioactivity and of radium introduced a new epoch into physical science. Not only was it necessary to revise old ideas and ways of expressing them, but new ideas and conceptions, and a new scientific jargon all developed in less than a decade. Atom, affinity, opaque, ray, electricity, matter and other more or less fundamental terms had to be redefined. To the layman, getting his science largely from the daily press, it was revolution; but to the patient worker in the laboratory it was evolution. He welcomed the new light as the sure reward of years of patient interrogation of nature; as the culmination of a long series of painstaking investigations.

Through the further classical researches of the two Curies, of Rutherford, Righi, Soddy, Becquerel and many others, the new science of radioactivity rapidly developed. The term atom became a figure of speech; matter and electricity became difficult to distinguish from each other, and what remained of scientific materialism received a blow from which it may never recover.

It need hardly be restated here, that radioactivity is an expression of the disintegration of atoms. The atom of radium is constantly breaking up and hurling into space minute particles at enormous

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[1] Contributions from the Botanical Department of the University of Missouri. No. 16.

[2] *Mem. N. Y. Bot. Gard.*, 4: 1–286, November, 1908.

velocities. The smallest of these particles, one one-thousandth the size of a hydrogen atom, bear negative charges (or, shall we say, *are* negative charges) of electricity, and are called electrons. They travel with about 95 per cent. of the velocity of light, penetrate "opaque" bodies, passing easily between and through their atoms, darken a photographic negative, and to a slight extent ionize a gas through which they pass. Streams of these particles constitute the β rays of radium and other radioactive substances.

The larger particles projected from radioactive bodies are about twice the size of a hydrogen atom, or two thousand times as big as the β particles. They move more slowly than the latter, and carry a charge of positive electricity. On account of their relatively greater size, they are much more effective ionizers, and correspondingly less penetrating to "opaque" matter than the β particles. They were named α particles by Rutherford. Streams of them constitute α rays.

Whenever a β particle, or electron, is started or stopped a penetrating electro-magnetic pulse in the ether (X ray) is developed. Such rays proceeding from radium are called γ rays. In addition to the emission of one or more of these three kinds of rays, radioactive materials give off a radioactive gas, called the emanation. In studying the physiological effects of radium, therefore, we have to consider these four factors—α rays, β rays, γ rays and emanation.

Our interest in the effects of radium rays on living organisms is enhanced by the discovery that radioactivity is widely distributed in nature. It is probable that all plants and animals are adjusted to a normal degree of radioactivity in their environment, or, in other words, are in a state of *radiotonus*. Professor J. J. Thomson was the first to discover that air bubbled through Cambridge (England) tap-water became decidedly radioactive, and the subsequent researches of numerous other physicists have taught us that this property belongs to the waters of most deep wells, to mineral waters generally, to freshly fallen rain and snow, to the spray at the foot of waterfalls, to the water of the ocean in certain localities, and quite probably to all spring waters.

After Elster and Geitel found radioactivity a property of the "fango," or mud from the hot springs of Battaglia, in northern Italy, other investigators discovered the same property in mud from various widely separated sources, in lava from volcanoes, in the sediments of springs, the sand of the seashore, and in sedimentary rocks.

The discovery, also made by Elster and Geitel, of the presence of radioactivity in the earth's atmosphere has been abundantly confirmed. Soil-air is more strongly radioactive than air above the surface. Evidence leads to the conclusion that the radioactivity of water, air, mud, rocks, etc., is due to the presence of the emanation of radium and other radioactive substances.

Radioactivity, therefore, must be recognized as a factor of plant environment, and plant physiology and the newer physics join hands. Here, as elsewhere, the boundaries between the different "sciences" break down.

Fig. 1 is from a photograph of a few of the preparations employed in the experiments about to be described. The three marked *R* are sealed glass tubes containing radium bromide. The figures indicate the degree of activity of the preparations in terms of the activity of uranium taken as a unit. Radium bromide of 1,800,000 activity is the purest salt thus far obtained. The lower right-hand tube contains radio-tellurium, which gives off only α rays.

The rod below the tubes is of celluloid, coated on one end with radium bromide of 25,000 activity. The radium coating is overlaid with one of celloidin for purposes of protection.

By means of the rod, not only the three kinds of rays, but the emanation as well, are available. The walls of the sealed glass tubes permit the β and γ rays to pass, but the emanation and the α rays not at all.

Radium coatings, such as those on the rod, were devised by Mr. Hugo Lieber, of New York City, and are a valuable aid in studying the physiological rôle of radium. The experiments of the writer, carried on for over three years at the New York Botanical Garden, were made possible solely through the great liberality of Mr. Lieber, who freely supplied all the standard preparations, several thousand dollars worth in all.

In none of the experiments did the radium itself come in contact with the plant tissues. The results noted were due to the action of the rays alone. When the sealed glass tubes were used, the effect was produced by the β and γ rays, acting together; when the radium coatings were employed, by the combined action of the emanation and the rays, α, β and γ.

To review the results obtained by other investigators is beyond the scope and purpose of the present article. Koernicke, Dixon and Wighman, A. B. Greene, Guilleminot and Abbe, not to mention others, have experimented on the action of radium rays on germination and growth, and, to a slight extent, upon other plant processes. There seems to be general agreement among them that the rays exert a retarding or an inhibiting effect, depending upon the activity of the preparation employed and the duration of exposure to the rays.

Germination is easily retarded or inhibited by exposing seeds while dry, or during imbibition of water. In one experiment ten seeds of "Lincoln" oats, after being soaked in water overnight, were exposed for eighteen hours to rays from the tube of 10,000 activity, by being placed with their embryo-sides in contact with the tube. Germination was retarded by this treatment. After being exposed for about 50 hours longer to the same preparation (67 hrs. 35 min. in all), the

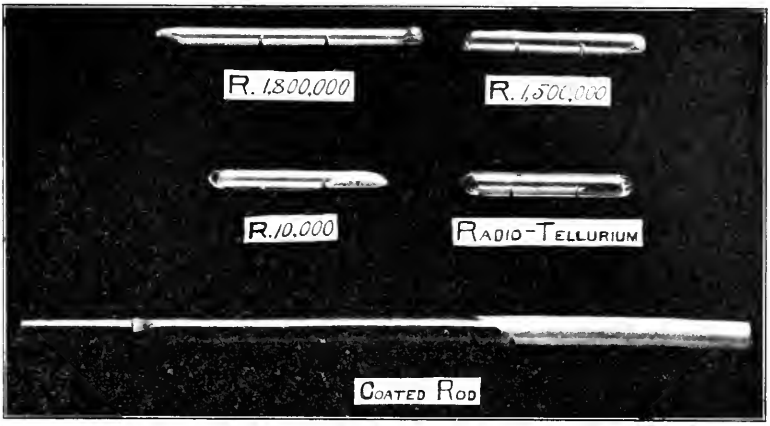

Fig. 1.

seeds, together with ten unexposed, but otherwise similarly treated seeds, were planted in soil in pots. The relative amount of growth in the two cultures at the end of five days after planting is illustrated in Fig. 2, where *R* is the culture exposed to the rays, and *C* the control (unexposed) culture. The growth of the root system was also greatly retarded by this treatment, and the root hairs on seedlings from exposed seeds were much longer than normally.

The effect of duration of exposure on the germination and growth of lupines (*Lupinus albus*) is shown in Fig. 3. The activity of the radium was the same in each case, 1,800,000, the seeds were exposed dry, and the length of exposure, from left to right in the figure, was 72 hours, 50 hours, 26 hours, 0 hours (control). The size of the largest seedling in the pan at the left doubtless indicates that the seed

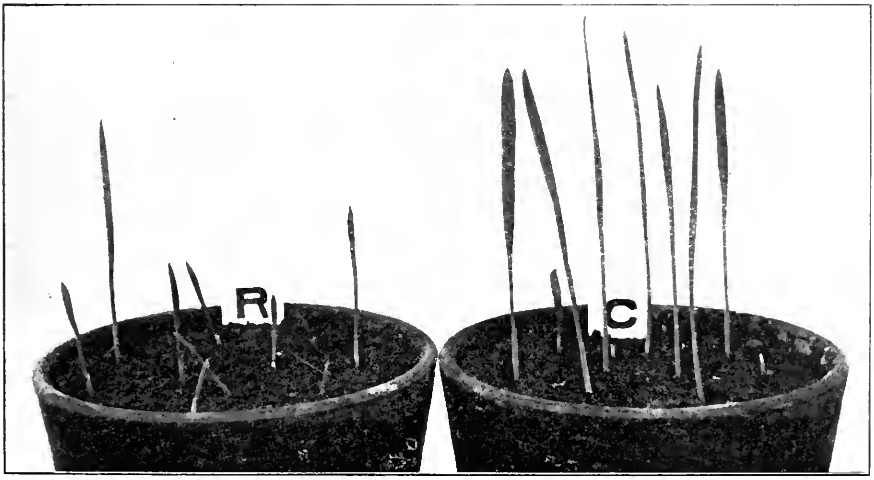

Fig. 2.

was poorly exposed. There is usually more or less difference in the resistance of individuals, but never as much as that apparently indicated, in the 72-hour culture. This and similar experiments confirm the results of Koernicke and others that the effect varies directly with the duration of exposure.

Fig. 3.

The relative effect of preparations of different activities is illustrated by the following typical experiment. Three sets, *a, b* and *c,* of six dry seeds of the white lupine were exposed to rays from sealed glass tubes of radium bromide by laying the tubes in contact with the hilum edges of the seeds. Care was taken to have the radium salt distributed evenly along the bottom of the horizontally placed tube. The activities of the preparations were: *a,* 1,800,000; *b,* 1,500,000; *c,* 10,000. A fourth set, *d,* served as a control. All exposures were for 91.5 hours. The seeds were then sown in soil in pots, and the comparative amounts of growth in the four cultures are shown in Fig. 4. The activity decreased from left to right. It is clearly demonstrated that the stronger the activity the greater the amount of retardation, under the conditions of the experiment.

Fig. 4.

An experiment to test the effect of a radioactive atmosphere on germination and growth was facilitated by the preparation by Mr. Lieber of a tube lined with the radium coating devised by him. This tube (*T,* Fig. 5) was connected with the upper tubulure of a glass bell-jar, resting air tight on a ground-glass plate. The lower tubulure was connected with an exhaust, so that air, entering the radium-lined cylinder, carried with it into the bell-jar the radioactive emanation. This air was delivered over pots of growing plants or freshly planted seeds in various ways, one of which is shown in Fig. 5, where the radioactive air passed over the soil-surface from an ordinary dovetail gas burner. The opening to the outlet pipe is under the flower pot. A control apparatus was similarly arranged, with the exception of the omission of the radium preparation. In one experiment, after a six days' exposure of timothy grass seed, sown unsoaked and covered with only an extremely thin layer of soil, germination and growth were shown to be retarded and the amount of retardation was greatest nearest the point of delivery of the radioactive air (Fig. 6). But where germinated seeds of the white lupine, with radicles marked 10 mm. back from the root-tip, were exposed for twelve hours in the radioactive atmosphere, growth was greater than that of a like number of roots similarly placed in the control jar. In one experiment, for

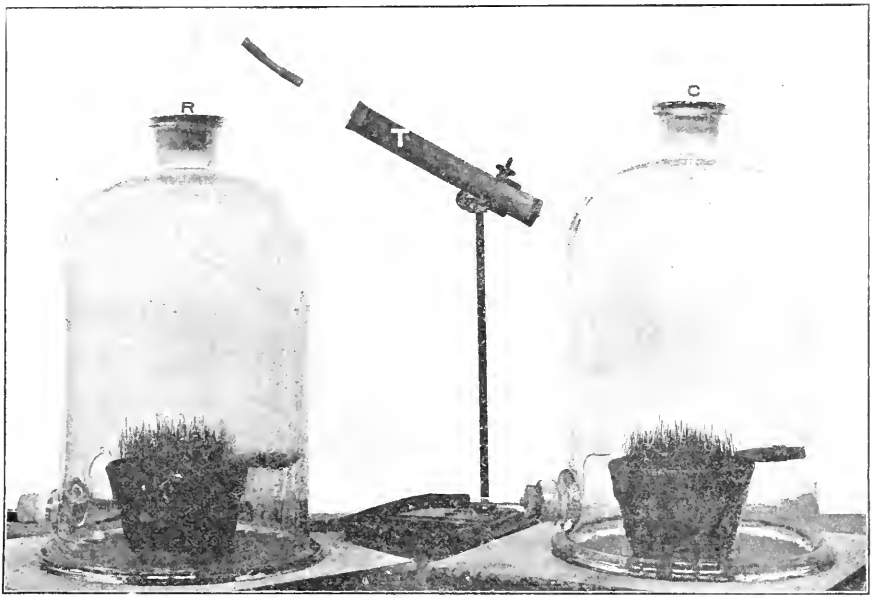

FIG. 5.

FIG. 6.

example, the total growth in 24 hours was, for the exposed radicles, 28.66 mm., and for the control radicles only 16.08 mm.

Thus it is seen that exposure to radium rays, though followed in some cases by a retardation or inhibition of function may, under certain suitable conditions of exposure and with certain tissues, be followed by an acceleration.

Excitation of function is further illustrated by the following experiment: In a flower pot of soil unsoaked seeds of oat were sown in three concentric circles, distant, respectively, 7 mm., 22 mm. and 45 mm. from the center of the pot. Into the soil at the center was inserted the sealed glass tube of radium bromide of 1,500,000 activity. The end containing the radium was about 15 mm. below the soil surface. A second pot was arranged in a like manner except for the substitution of an empty glass tube for the radium tube. At the end of 106 hours the seedlings from the exposed seeds were much taller than those in the control pot (Fig. 7), the amount of stimulation being greatest in the outer circle of plants and least in the inner circle. At the end of the 106-hour period the radium tube was placed in the control pot and the empty glass tube in the pot *R*. Following this change the seedlings in *CR* grew faster than those in *R*, now serving as a control. Thus it was possible to accelerate the growth of the seedlings in either pot at will by transferring the radium tube from one culture to the other.

Fig. 7.

The fact that incandescent gas mantles contain a large percentage of thorium, a radioactive substance, suggested the following experiment. On the surface of soil in a pot was sown a row of timothy grass seed, and over this row and at right angles to it, was suspended a fresh, unburned mantle at a distance of three or four millimeters above the seeds (Fig. 8). Germination and subsequent growth were both re-

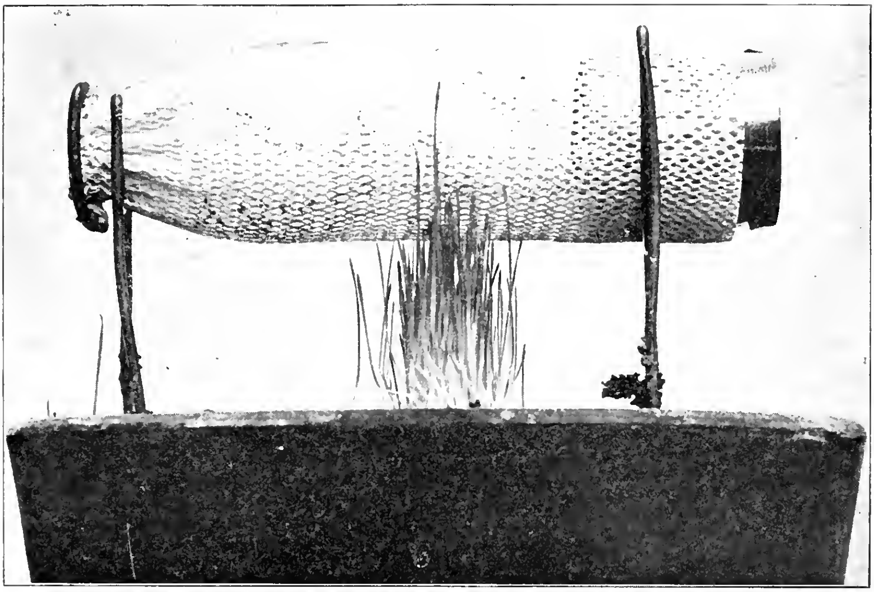

FIG. 8.

tarded by the rays from the mantle, and Fig. 9 shows the appearance of the culture seven days after the experiment was started.

The influence of radium rays on photosynthesis was tested in several ways. For example: A nasturtium (*Tropæolum*) plant was placed in sunlight after having been in darkness for 18 hours. Under one of the leaves, and lightly in contact with it, was placed a Lieber's coated rod of undetermined (probably 25,000) activity. After twenty-four hours the leaf was dechlorophyllized and stained with iodine to test the presence of starch. Starch was almost entirely wanting in the part of the leaf that was directly over the radium-coated rod, but was

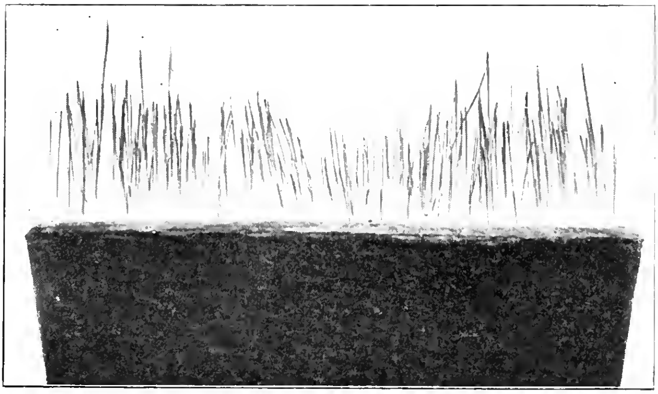

FIG. 9.

present in other portions of the leaf. The result was recorded by exposing the leaf to sunlight in contact with the velox paper in a printing frame. The region lacking starch, being more translucent, gave the darkest image on the velox paper (Fig. 10).

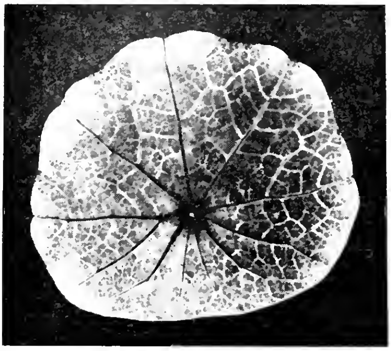
Fig. 10.

It was found possible to increase the rate of respiration of germinating seeds by means of the rays, and alcoholic fermentation was also accelerated by suitable exposure, as follows: Five fermentation tubes were filled with equal quantities of a mixture of 2 gm. of a compressed yeast cake in 250 c.c. of a 5 per cent. solution of cane-sugar. Into four of the fermentation tubes were placed sealed glass tubes as follows: $RaBr_2$ 1,500,000 ×; 10,000 ×; 7,000 ×; radio-tellurium. The fifth served as a control. At the end of about three and one half hours the cultures were photographed (Fig. 11). It is clearly shown in the figure that the rate of alcoholic fermentation, as measured by the evolution of gas, was accelerated by the rays; most by the preparation of 1,500,000 activity, least by that of 7,000 activity, and to an intermediate degree by the other preparations.

Various attempts have been made to detect a tropistic response, or curvature of a growing organ toward or from a radioactive source. The phosphorescent light of radium has not been found intense enough to call forth phototropic curvatures, and the existence of a true *radiotropism* is yet to be demonstrated. Koernicke found that seedlings

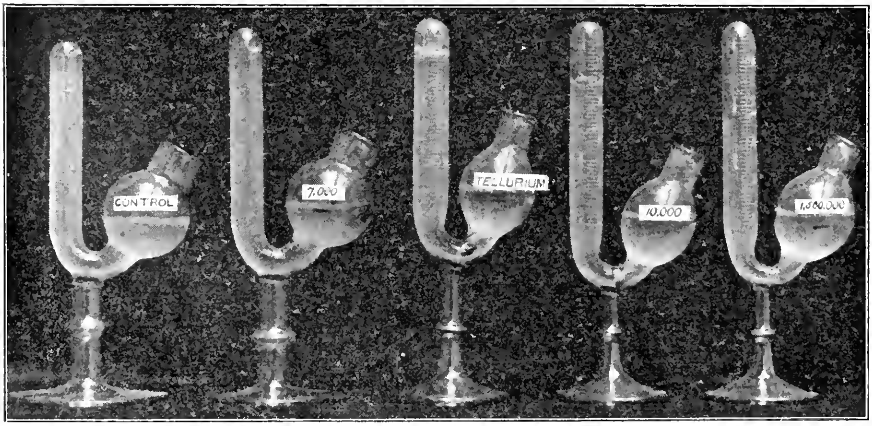

Fig. 11.

grown from exposed seeds were still sensitive to gravity and unilateral illumination, and the experiments of the writer confirm this result. Under certain conditions of exposure of corn grains, however, the seedlings failed to respond to gravity, and grew horizontally, close to the soil surface. Thus, in one experiment, the grains were exposed for twenty-seven hours to rays from radium bromide of 1,800,000 activity, and all of them showed this tendency to a greater or less degree (Fig. 12, pot 27). Whether geotropic sensibility was destroyed by the exposure is difficult to say, for histological examination showed the tissues to be so abnormal that it is possible the plants could not have stood erect even if they had been able to detect the stimulus of gravity.

FIG. 12.

All attempts to obtain a curvature of growing organs or plants toward or from a radium tube or radium-coated rod proved unsuccessful, but when a sealed glass tube of radium bromide is suspended horizontally in tap-water, or in nutrient solution, in which radicles of white lupine seedlings are growing vertically, the tips of the roots may be made to curve toward the radium. Such a result is illustrated in Fig. 13. In this experiment the radium tube was originally about 5 mm. distant from the root-tips. Whether this result was due to the direct influence of the rays, or to some undetermined condition established by them in the liquid can not yet be decided.

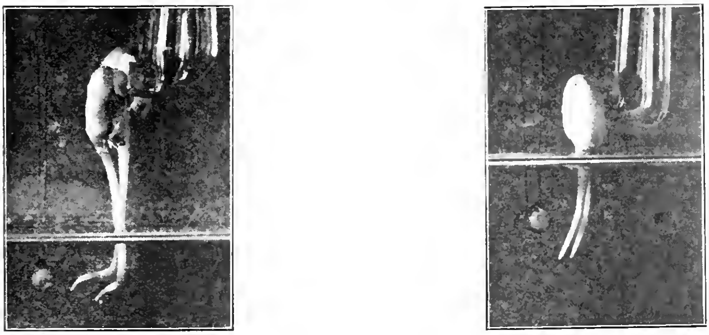

FIG. 13.

The above experiments were all confirmed by repetitions, and clearly indicate that radium rays act as a stimulus to the various physiological processes of plants. If the strength of the radium, the duration of exposure, and other conditions are suitable, the response is an excitation of function, but if the method of treatment is otherwise, the radium too strong, the exposure too prolonged, the result is a retardation, or complete inhibition of function, or the death of the plant. There are not only differences in sensitiveness between individuals, but also between different species and different tissues. As in the case of animals, embryonic and younger tissues are more sensitive than those that are older and more mature.

THE WORK OF BOARDS OF HEALTH[1]

BY DR. GEORGE A. SOPER
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THE spirit of the laws by which matters of public health are administered rests upon the theory which underlies all forms of government, that is, that the state has the power to compel the ignorant, the selfish, the careless and the vicious to so regulate their lives and property that they shall not be a source of danger to others. It is an expression of the idea that the interests of no man can exceed the interests of his fellows. The welfare of the many is the supreme law.

Extraordinary powers have from early times been vested in the authorities charged with administering sanitary laws. The highest courts have declared that the administration of public health laws is fundamentally important and entitled to the support of the police power of the state. Public health authorities are in effect police officers charged with a special jurisdiction over the conditions which cause, aggravate or predispose to disease. In the exercise of their remarkable powers health authorities may restrain persons from contact with others, they may enter upon and even destroy private property and may exercise supervisory jurisdiction over trades and occupations.

Many years ago, the almost autocratic power enjoyed by health authorities was much more necessary than it is at present, for the highly contagious diseases have, through the operation of health laws, better personal and household hygiene and municipal sanitary works, been relegated to a comparatively unimportant place as a cause of death. Epidemics of high mortality and vast extent rarely take place in civilized countries to-day, and the need of a prompt, decisive exercise of great authority in this direction is consequently less often necessary than formerly.

At the same time, a new class of duties is growing upon health authorities. Some of these duties are plainly within the proper functions of health boards, while others appear to be less so. Among the obviously proper duties referred to are vaccination, the manufacture and distribution of antitoxin, the control of methods of sewage disposal and the sanitary management of milk and water supplies. Of less obvious appropriateness is the regulation by boards of health of such matters as the discharge of excessive quantities of smoke into the atmosphere of cities, the suppression of street noises, the hygienic care

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[1] Paper read before a joint meeting of the National Municipal League and the American Civic Association at Pittsburg, Pa., November 16, 1908.

of the food, clothing, exercises and amusements of school children. It is probable that these matters should be made the subject of regulation in the public interest, but should the board of health be the instrument chosen to regulate them?

Obviously some limit should be placed upon the exercise of the power possessed by boards of health when questions not strictly germane to the sanitary welfare of the public are concerned. If no such limit is placed, it is difficult to understand where the activities of boards of health are to cease. Almost every act and occupation and nearly every feature of city life may be construed as having some bearing upon public health and welfare. Before a board of health sets out upon a campaign of more esthetic than sanitary value it should be certain that all its simple and essential duties are being efficiently discharged. There is often much inconsistency in public health work.

So extensive and so numerous are the conditions of modern civilization which certainly affect health, that boards of health generally do not pretend to cover them all. For example, the construction and maintenance of public water supplies and sewerage systems, although undertaken by the public at the public expense, are not conducted by health authorities but by private corporations or special municipal departments. Likewise the collection and disposal of garbage, and even the cleaning of privies, is often done by other than public health authorities.

There is something incongruous about a board of health conducting a crusade against smoke and noise and at the same time allowing the streets to be filthy with dirt and dust and offensive with accumulations of fermenting garbage. Again a great deal of the attention of health boards is occupied with alleged private nuisances which affect comfort but not health. The history of every city is a record of more and more strict regulations to minimize the unpleasant as well as the unsanitary conditions of household life.

The work of boards of health has been, on the whole, very decidedly for the advancement of the general welfare. The great reduction in the general death rate and the more wholesome and agreeable conditions of living of to-day as compared with those of a generation ago, bear ample testimony to this success. If it be objected that other factors have been at work to improve the sanitary conditions of cities, it must be answered that much of the inspiration for this other work has come from health authorities. It should never be forgotten that it is sanitation which has made the growth of cities possible.

Having thus briefly referred to the scope and bearing of public health work we may pass to a consideration of the relation of city, state and nation in protecting the public health.

The authority exercised by public health boards is derivable from the state. In the United States the management of the internal affairs of each separate state is left, for the most part, to the state concerned. Municipal charters are obtained from the state governments and in these charters the power to regulate conditions affecting public health are specifically granted. Cities and towns thus owe responsibility to the state governments and are answerable to them to a greater or less extent, depending upon local circumstances. In Massachusetts local boards of health are comparatively independent of the state authority, while in New York the state department of health is a central body to which the local boards of health are closely tributary.

State health authorities are in no case responsible or answerable to the general government. There is no national board of health.

In the management of health matters the smallest unit of responsibility is a municipal health officer or municipal board of health; the largest the state health officer or board of health. Whether municipal or state, the functions of health authorities are very much the same. The main differences arise from the differences in area over which the authorities are required to exercise supervision. Local boards have charge of the conditions which occur in the several localities in a state; they take cognizance of individual houses and of persons. The ultimate units over which state boards exercise jurisdiction are municipalities.

It is the first duty of all health boards to collect vital statistics, to collate them in tabular form, and to interpret these data so as to show the state of the public health. Local boards of health collect reports of deaths and of contagious and other diseases from physicians, interpret these data, for the benefit of the districts in which they apply, and then forward them to the state authorities. The state authorities so obtain a knowledge of the health in various sections of the state and are so enabled to judge the relative healthfulness of the different localities. An excessive prevalence of disease in one place can thus be promptly detected.

The methods of collecting vital statistics are often unsatisfactory and the results frequently deceptive. It may be remarked in passing that vital statistics are to-day available for only a part of the people of the United States, except during years when this government makes a census enumeration. The census returns are themselves unsatisfactory. In this respect the United States government is behind nearly every civilized country in Europe. The fault lies with our municipal and state governments.

In interpreting death rates careful account must be taken of the marriage and birth rates, total population, migrations of population, and other factors; and it would be well for boards of health to charge themselves with collating as well as collecting these vital statistics, in a more intelligent manner.

When the evidence of vital statistics indicates the presence of an unsanitary condition through an excessive prevalence of some communicable disease, investigations are commonly made to determine the nature of the difficulty. This is often a troublesome and uncertain task. But when the difficulty is once discovered it is usually a simple matter to prescribe the remedy.

In very recent years sanitary investigations have been made much more definite and effective by the applications of bacteriology, chemistry and pathology, and a new class of professional men has been developed for laboratory and field work of the highest and best order. These persons we may call sanitarians or, better, hygienists.

The second main branch of public health work is the suppression of communicable diseases. Suppressive measures include the establishment of quarantine, the isolation of patients, disinfection, vaccination and the management of epidemics. Contrary to the custom of twenty years ago, all the best work in these directions to-day is based upon a scientific knowledge of what we may call the natural history of disease. In all these matters of control the dictum of the health authority is supreme. It can be resisted only through intervention by the courts.

The third main branch of public health work is the abatement of nuisances. The practical work of suppressing unsanitary conditions is done by health authorities by recourse to special statutes and local regulations made by the authorities themselves and termed "sanitary ordinances" or "sanitary codes." Offenders against these laws and regulations are brought before proper magistrates and fined. A board of health exercises the unique function of both making and enforcing the law.

It may be extremely difficult to determine what does and what does not constitute a nuisance. For practical purposes it is often considered that anything which is detrimental to health or which threatens danger to persons or property may be considered and dealt with as a nuisance.

Interesting work for the suppression of disease lies in educating the public, the medical profession and the health authorities as to the causes of and means of preventing the transmission of disease germs. This is one of the newest and most successful branches of public health work which has been undertaken for many years. It is based on the fact that people are not careless in sanitary matters because of a wilful or vicious design against the public welfare; they err through ignorance. By educating the less fortunate concerning the ways in which diseases are transmitted and showing how they can be prevented, substantial benefit results.

This educational work is carried on by the daily papers, the medical papers, special bulletins and magazines, by lectures, by clinics, by congresses and, to some extent, by schools. Sanitary societies and public health associations deserve special credit for good work in arousing the public to the need of better public health work.

At the same time it is regrettable that arguments have been made and movements have been initiated in the name of public health which have had no foundation in fact or scientific principle. The cause of public health has always been a favorite theme alike for the charlatan and the statesman.

By the remarkable advance in that composite body of knowledge known as sanitary science much of the quackery of fraud and the deceptions of ignorance are being dispelled from public health work, and we may confidently look forward to the time when persons who have had adequate training and experience in this direction will be looked upon as the proper sanitary teachers.

In the campaign of sanitary education which is going on it is a deplorable fact that the universities and colleges of the United States are singularly backward. With a few notable exceptions, there is scarcely a school for higher education in the United States where a competent knowledge of hygiene can be obtained. In spite of the fact that many of the largest and most prominent universities have had severe experiences with typhoid they have been exceedingly slow in providing proper facilities for the teaching of hygiene. One of the greatest needs of to-day is the want of competent teaching for health officers, physicians, engineers and others, who may wish to obtain a complete and practical knowledge of their profession. In the absence of suitable facilities for the education of health officers the United States is decidedly behind European countries.

In the management of communicable diseases the principles of isolation, disinfection and vaccination, have been referred to. It remains to mention the help that may be afforded by the establishment of laboratories for the diagnosis of suspected cases of communicable diseases. Laboratories where examinations may be made of sputum, blood, urine, stools and other pathological specimens, are one of the newest developments in public health work, but they have been in operation sufficiently long to make them seem indispensable. By their means early and obscure cases of tuberculosis, typhoid fever, diphtheria and other too common preventable diseases may be discovered, and with a precision and promptness generally impossible in private medical practise. Along with pathological work of municipal public health laboratories facilities are often provided for the analysis of water, milk, food and drugs. Any citizen may send specimens to these laboratories for examination, and is entitled to a report without charge.

Every board of health should have the benefit of laboratory assistance of this kind. Municipal boards in large cities can afford to maintain them, but for the small city and village other provision must be made. Here the state can render valuable assistance and maintain laboratories for the benefit of municipalities which can not have them.

In addition to the measures of prevention and suppression which have been mentioned reference should be made to the preparation and distribution of antitoxin by boards of health. Here we have an application of the laboratory principle applied to the production of a remedy rather than to the discovery of the cause of disease. Antitoxin is a curative measure which may be and is applied more often than not to isolated cases of diphtheria. The beneficent results which have followed the use of this agent in combating one of the most common and fatal of household diseases are unquestioned, but it must not be forgotten that in supplying antitoxin without charge, boards of health lay themselves open to the charge of competing with private manufactories which prepare the same product and are presumably in a legitimate business to make money.

Results seem to show that it is desirable for boards of health to supply antitoxin, but the principle involved is an interesting one. If antitoxin is to be supplied gratis by boards of health, should not those boards also supply disinfectants, concerning which there are no greater frauds in the American markets to-day? And if antitoxin and disinfectants, why not other things such as indispensable articles of clothing?

To enumerate all the functions of boards of health, local and state, would far surpass the necessary limits of this paper, but enough has been said to show warrant for endorsing most of the work being done to approve the extension of some and the limitation of others of the ever-growing activities of health bureaus. A long paper could be written on any of a dozen phases of this subject.

Taking a rapid review of the subjects covered here, we may remark first that boards of health have ample power. The standards of public health and municipal hygiene are continually growing higher.

The dangers from disease in gross epidemic form are becoming less and less, and in their place a new set of hygienic standards is being erected. Some of these new standards verge upon the realm of esthetics. To what extent boards of health are right in extending their efforts to improve municipal conditions which bear remotely, if at all, on disease and death, but undoubtedly affect public comfort, is a question for debate.

To be effective health work must be cooperative. Statistics must be promptly and accurately collected by the ultimate units of sanitary authority, municipal health boards, and transmitted to boards having jurisdiction over larger territory. Whether or not the largest unit of health control should be the state or the nation is a question which this paper need not discuss. It is to be remembered in this connection, however, that state boundaries are only imaginary lines and that some kind of understanding is indispensable between neighboring states for some forms of sanitary control, such, for example, as the purity of water supplies, the management of epidemics and the regulation of milk and other food products. Likewise the management of quarantine, a subject of importance to large portions of the population of the nation, should not be left to the regulation of any particular locality, but should be managed in accordance with laws which are general for the common welfare.

First and foremost among the defects and needs of public health administration must be placed the want of adequate knowledge of the principles and practises of public health work on the part of officials having jurisdiction. It is a deplorable fact that special professional qualifications are not as a rule required of health officers in the United States.

If there is any department of municipal government which should be taken out of politics and put upon a high plane of professional efficiency, it is public health work. Generally, in the United States, appointment upon a health board means a thankless and gratuitous service performed for the sake of the small honor which is supposed to go with it. Where a salary is connected with the position the office is too often a reward of political rather than professional merit.

Until the need of high-class health work is demanded, appreciated and properly rewarded by compensation in money and honor, men will not be prepared by the schools for a life-work in the public health service, and the most needed improvement in the work of boards of health will not be made.

A BIOGRAPHICAL HISTORY OF BOTANY AT ST. LOUIS, MISSOURI. IV

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ONE of the best known of the botanical collectors of this country who worked shortly after the middle of the last century was August Fendler. He, like numerous others, came to America from Germany in the late thirties. From 1864 to 1871 he lived at Allenton, Missouri, about thirty miles from St. Louis. While living at Allenton Fendler arranged the first botanical specimens in the herbarium which was just being started by Henry Shaw for his Botanical Garden. These numbered about 60,000 and consisted of the herbaria of Bernhardi and Riehl, the latter containing a considerable number of local species. Because of his extensive and excellent collections, he became known to botanists and botanical institutions. While he was widely known by reputation, he seems not to have been well known personally, because of his excessive diffidence.

August Fendler[17] was born August 10, 1813, in the town of Gumbinnen, in eastern Prussia. When he was six months old his father died, and two years later his mother married again. His parents had but scanty means and his school training for a number of years could scarcely be called schooling. When about twelve years old he was sent to the Gymnasium, and was here for about four years, when his parents were obliged to take him from school because of financial troubles. He was apprenticed to the town clerk's office, and here began to think of traveling in foreign countries.

At the end of his apprenticeship he had an offer to accompany a prominent physician as his clerk in a journey of inspection along the Russian frontier of Prussia where the cholera was beginning to be feared. Fendler was soon in the midst of the cholera and remained for some time, returning home when the disease had abated. He now learned the trade of tanning and currying during the next two years. In the fall of 1834 Fendler was admitted to the Royal Gewerbeschule, but the strain upon his already frail health caused him to abandon it after finishing the first year with credit.

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[17] Canby, W. M., *Bot. Gaz.*, 9: 111–112, 1884; 10: 285–290, 301–304, 319–322, 1885.

Gray, Asa, *Amer. Jour. Sci. and Arts*, 3d series, 29: 169–171, 1885.

Sargent, C. S., "Silva of North America," 12: 123–124, 1898.

In the fall of 1835 he started with a knapsack upon his back from Berlin as a traveling artisan, passed through parts of Silesia, Saxony, to Frankfort, down the Rhine, and finally coming to Bremen. Early in the spring of 1836 he embarked for Baltimore, Maryland, arriving with but two dollars in his pocket. In Philadelphia he worked in a tannery for a time, then went to New York and worked at the lamp manufacturing business. The financial panic of 1837 caused this business to be closed in the spring of 1838.

FIG. 13. MR. AUGUST FENDLER, at about the time he lived at Allenton, Mo.

Having made up his mind to go to St. Louis, he started as soon as possible. The easiest way was from New York to Albany by boat, thence to Buffalo by canal, to Cleveland by steamer, to Portsmouth on the Ohio River, and then down the Ohio and up the Mississippi by steamboat. This trip took thirty days.

In St. Louis, which had then about 13,000 inhabitants, he soon got employment, but decided to go to New Orleans because of the approaching winter. He left St. Louis about Christmas, 1838, on foot, with his knapsack on his back; he crossed the Mississippi and walked along through the thinly settled forests of Illinois, the cane-brakes of Kentucky, and a part of Tennessee, where he fell in with two others going to the same destination. At the mouth of the Ohio they joined in buying a skiff and set out for New Orleans in it. They soon were caught by a steamer going their way and they boarded her and abandoned their skiff. Upon arriving in New Orleans the talk about Texas decided him to go farther west, and he arrived in Galveston in January, 1839. He stayed in Texas about a year and then returned to Illinois where he taught school for some time.

In the fall of 1841 he found an uninhabited island in the Missouri about three hundred miles above St. Louis, and he took up his solitary residence there. When the spring rise came it caused him to leave.

In 1844 he sailed for home, and while on this trip first learned that sets of dried plants might be sold. On his return to America and to St. Louis he began to collect and was aided by Dr. Engelmann in naming his specimens. He visited different parts of the country between Chicago and New Orleans for the purpose of collecting. Dr. Engelmann commended him to Dr. Asa Gray, and he was furnished with the authority to accompany some troops which were being sent to Santa Fé, so that he had free transportation for himself and luggage. He returned to St Louis in the fall of 1847. In the spring of 1849 he started on another collecting trip to the West. He was unsuccessful, having lost most of his stock of drying papers in a flood, and he was forced to return to St. Louis. Upon his arrival here he found that all of his large collections and notes and journals had been destroyed in the great fire which burned much of the business section of the city during his absence. In 1849 he embarked for Panama, and after four months again returned to Arkansas, and finally went to Memphis, where he went into business. In 1854 he went to Venezuela and collected for four years, during this time exploring alone mountain ranges which were scarcely known at that time. He made very large collections, which are of great value. He returned to Missouri in 1864 and bought a tract of land in the town of Allenton, about thirty miles west of St. Louis. This he began to clear and cultivate in company with his half-brother, who was half-witted, and who always was dependent upon him. Here he remained for seven years, with the exception of a month spent in the Gray Herbarium, assisting in its arrangement. During this time Mr. Letterman became acquainted with him, and from 1870 to 1871 they met two or three times a week and nearly every Sunday with green plants to be identified. He seems to have collected but little in the vicinity, but was very familiar with the plants of the general neighborhood. After clearing his land and putting up his house, mostly with his own hands, he spent most of his time writing a book. This is undoubtedly his "Mechanism of the Universe," which was unfortunately published at his own expense later. Failing health forced him to dispose of his farm and remove to another climate. In 1871 he sold the farm and left for Europe, intending to live there the rest of his days. He, however, returned and settled at Wilmington, Delaware, in 1873. While here he finished his book and published it. Repeated attacks of rheumatism compelled him to seek a warmer climate, and he and his brother went to the island of Trinidad. They lived at Port of Spain, landing in June, 1877; here the remainder of his life was spent in making botanical observations and collecting, especially among the ferns. Advancing age restricted his efforts to the immediate neighborhood, and when this was exhausted he did but little. His death occurred in November, 1883.

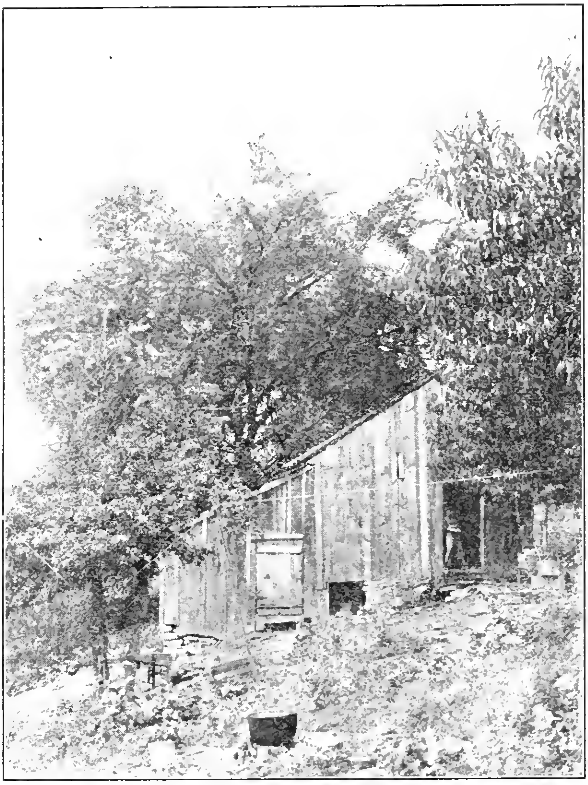

FIG. 14. HOUSE BUILT BY AUGUST FENDLER IN ALLENTON, MISSOURI, and occupied by him during his residence here from 1864 to 1871. The small ell has been added by subsequent owners.

An appreciation of his work from one who knew him best follows:

> It is needless to say that Fendler was a quick and keen observer and an admirable collector. He had much literary taste, and had formed a very good literary style in English, as his descriptive letters show. He was excessively diffident and shy, but courteous and most amiable, gentle and delicately refined. Many species of his own discovery commemorate his name, as also a well-marked genus, *Fendlera*, a Saxifragaceous shrub which is winning its way into ornamental cultivation.[18]

[18] Gray, Asa, *Amer. Jour. Sci. and Arts*, 3d series, 29: 169, 1885.

Dr. F. Adolph Wislizenus came to America from Germany in 1835; he landed at New York and lived there for the next two years. In 1837 he went west, settling near Belleville, Ill. Two years later he came to St. Louis and lived in that city practically all the rest of his life. He is not known to have performed any botanical work in the vicinity of St. Louis, but he is included in the present paper because of having made a very considerable collection of plants in New Mexico, Mexico, and other parts of the great American arid plain. This collection was one of the first from the region visited, and is considered especially important because Dr. Wislizenus was one of the first to give an accurate. scientific account of the sections visited by him. This is especially true of Mexico, of which there were very erroneous and distorted ideas in the United States.

FIG. 15. DR. ADOLPH WISLIZENUS; by permission of the St. Louis Academy of Sciences, from a photograph in their possession.

Dr. Frederick Adolphus Wislizenus[19] was born in 1810 at Koenigsee, in Schwarzburg-Rudolstadt, one of the numerous tiny German principalities of that period. He was the youngest of three children of a Protestant minister whose ancestors were said to have fled from Bohemia, victims of the religious fanaticism which resulted in the persecution of Hus and his followers.

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[19] Engelmann, Geo. J., *Trans. St. Louis Acad. Sci.*, 5: 464–468, 1890.

Sargent, C. S., "Silva of North America," 6: 94, 1894.

Wislizenus, F. A., "Memoir of a Tour to Northern Mexico," 1–141, 1848. POP. SCI. MONTHLY, 52: 643, 1898.

Wislizenus studied medicine at the University of Jena in 1828, and later at Göttingen and Würzburg. He was a member of the "Burschenschaft," but escaped arrest when that was broken up by the authorities. He followed his friend and teacher, the great clinician Schoenlein, to Zürich and there joined an expedition to aid Mazzini in his struggle against Austrian rule; but the Swiss troops disarmed them on the border so he was forced to return to his studies.

Wislizenus graduated in Zürich in 1834 and soon sailed for New York, where he began to practise his profession in 1835. Here he remained two years writing constantly for the German papers of the city. He then went west in 1837 and joined some of his fellow-exiles who had settled in St. Clair County, Illinois. In 1839 he came to St. Louis and immediately seized an opportunity to accompany an expedition of the St. Louis Fur Company for trading with the Indians. He thus went far into the Northwestern country towards the source of the Green River in the Wind River Mountains. When the expedition started to return he joined a band of Flat-head and Nez Percé Indians. He thus crossed the Rocky Mountains to Utah and went as far as Fort Hall, the most southern post of the English trading company. Here he could find no guide to take him to California, so he returned; crossing the Green and the south fork of the Platte, he followed the Arkansas to Missouri. During this trip he had no facilities for making scientific observations and collections, so it was wholly without any such results.

On his return to St. Louis in 1840 he resumed his practise of medicine He was identified with early efforts towards the establishment of an Academy of Science, and aided Dr. Engelmann in his efforts to found a botanic garden, and was an earnest worker in the Western Academy of Science. He soon gained a lucrative practice, but as soon as the opportunity offered he was again in the field. He joined a trading expedition to Mexico, well equipped this time with instruments and apparatus for scientific work. In Santa Fé they first learned of the war between Mexico and the United States, but Wislizenus obtained a pass and proceeded to Chihuahua, where he with other Americans was seized and imprisoned. He was sent to a small mountain town of the interior and there had ample opportunity to carry on his collecting and observations in the neighborhood during the winter. Upon the arrival of Col. Doniphan's troops in the spring he was released and accompanied them in a professional capacity until their disbanding at New Orleans in 1847, when he returned to St. Louis.

Senator Thomas H. Benton became interested in him and his experiences in Mexico, and finally was the cause of his being summoned to Washington and being requested to prepare for publication the results of his investigations. His resulting "Memoir of a Tour to Northern Mexico in 1846 and 1847" was considered important enough so that the senate ordered 5,000 copies printed for distribution. This publication gave a good account of the country which was then much misunderstood and misrepresented, and resulted in correcting many erroneous ideas regarding that section of the American continent. It contained many very valuable data concerning the meteorology, geology, topography and botany of the region. Among the valuable results of this tour was a botanical collection containing many new plants which were classified and described by Dr. Geo. Engelmann, of St. Louis, who commemorated the valuable services of Wislizenus to science by applying his name to a new genus, *Wislizenia,* as well as to several of the new species of the collection.

Wislizenus again returned to St. Louis from Washington upon the completion of his report, and served faithfully during the cholera epidemic of 1849. As soon as this was over, however, he went to Constantinople in 1850 to bring back with him as his bride, Miss Lucy Crane, a sister-in-law of Hon. Geo. P. Marsh, whom he had met while in Washington. After visiting his old home in Thüringen and the large cities of the Old World, the two returned to the United States. Leaving his wife with her friends in the east, he went to Panama and California in search of a more desirable location. But he again returned to St. Louis and finally settled down permanently. He was one of the founders of the St. Louis Academy of Science and an active worker and one of the officers of the St. Louis Medical Society and of the Western Academy of Sciences. He was for many years president of the German Medical Society of St. Louis. His barometrical observations and his botanical and mineralogical collections, together with his memoir, are distinct additions to science. He was interested in meteorology from 1858 till his death, and in 1861 he commenced to study the atmospheric electricity with the belief that this would be of value in connection with meteorology. He discontinued this study, however, upon arriving at the conclusion that it was valueless in this connection—a fact which is now generally acknowledged. His last days were spent in seclusion, he being closely confined to the house by his infirmities and the loss of his sight. He died on September 22, 1889, in his eightieth year.

In 1851 there began a most important movement for the advancement of botany in St. Louis.[20] In that year, Mr. Henry Shaw, while on his last visit to Europe, first conceived the idea of establishing for himself a country estate on lines similar to those of many of the large English ones. In fact he had already started to build a home in the country district west of St. Louis.

This idea of a large private estate seems to have soon become changed to that of a botanical garden, for in 1857 he commenced active opera-

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[20] Trelease, Wm., Mo. Bot. Garden Report, 1: 84–90, 1890. *Plant World,* 5: 1–4, 1902. "The Academy of Science of St. Louis," Pop. Sci. Monthly, 62: 118–130, 1903. "The Missouri Botanical Garden," Pop. Sci. Monthly, 62: 193–221, 1903.

tions to this end. He even at one time planned a grand school of botany with all the appendages and equipment necessary for a college of botany. This was modified in its first inception, but has been carried out to a degree. Very soon he built a botanical museum, bought herbaria and built greenhouses in which tender and exotic plants might be grown, while the grounds themselves were planted with many of the more hardy species. In 1859 he secured the passage of an act of the Missouri state legislature enabling him to deed or will to a board of trustees such property as he might wish, to be used for the maintenance of the Missouri Botanical Garden, as he prophetically named it. In 1885 he founded the Shaw School of Botany in connection with Washington University of St. Louis and provided for very close relations between the school and the garden. The estate deeded for the use of the garden was valued at about one million two hundred and fifty thousand dollars. This has increased very materially in value with the rapid rise in real estate in and about St. Louis. From the small beginnings of a private estate, the garden has developed until there were in cultivation in 1906, over seventeen thousand species and varieties of living plants; fifty-five thousand books and pamphlets in the library, including a very fine collection of pre-Linnæan works, and five hundred and sixty thousand sheets of dried specimens. The garden has issued eighteen annual reports, and is in exchange relations with nine hundred institutions interested in botany, gardening, horticulture or forestry. The library is one of the finest of the botanical libraries of the world, and all resources of the garden are placed at the free disposal of those capable of using them. Thus Mr. Shaw's life-work has reached its fruition, and a fitting memorial is rising steadily to more and more impressive proportions.

Henry Shaw[21] was born in Sheffield, England, July 24, 1800. He was the eldest of four children. His father was a manufacturer of grates, fire irons, etc., and owned a large establishment. Henry's early education was obtained at Thorne, a neighboring village, and his favorite place for study was an arbor in the garden. He was later transferred to Mill Hill, about twenty miles from London. This was termed a "dissenting" school, but was also considered one of the best private schools in the Kingdom. He remained here about six years, leaving probably in 1817, thus finishing his schooling. He studied while here considerable Greek, more Latin, more than the average amount of mathemathics, French, and undoubtedly German, Italian and Spanish. With this scholastic training he began to assist his father at the home establishment for a year, after which he accompanied him to Canada. In this same year, 1818, his father sent him to New Orleans, mainly to investigate cotton raising. He stayed in Louisiana but a short time,

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[21] Dimmock, Thos., *Mo. Bot. Garden Report,* 1: 7–25, 1890.

as he did not like the climate nor were there financial inducements for his doing so. He was now his own master and decided to go north and try his fortune in the then small and remote French trading post known as St. Louis. He accordingly embarked upon the *Maid of New Orleans,* and after a long and tedious voyage landed at St. Louis on May 3, 1819.

FIG. 16. HENRY SHAW; from a watercolor painting at the Missouri Botanical Garden, by permission of the Director.

He began business on the second floor of a building which he found for rent, and for a time lived, cooked and sold his small stock of cutlery in this one room. The capital with which he bought his first stock of goods was furnished by his uncle. While Mr. Shaw's main object at this time was to make money, and while he denied himself many youthful enjoyments, he still did not thus deny himself beyond reasonable limits.

He had been succeeding in business, and when the balance sheet for 1839 was struck it showed to his own great surprise a net gain for the year of $25,000. His figures were gone over again and again until there could be no doubt of the fact. It seemed to him that "this was more money than any man in my circumstances ought to make in a single year." Accordingly, the following year, when opportunity offered, he closed out his business. At this time he was forty years of age, physically and mentally unimpaired, and vigorous, a free man, and the possessor of $250,000, equivalent to more than $1,000,000 at the present time.

In September 1840, Mr. Shaw made his first visit to Europe, stopping on his way at Rochester, New York, where his parents and sisters resided. He took an extended tour on the continent and, returning to St. Louis in the autumn of 1842, arranged his affairs for another absence in Europe. This lasted for about three years, during which time he visited all of the accessible European localities, together with Constantinople and Egypt. A journey to Palestine was prevented by the prevalence of the plague in that country.

Early in 1851 his last trip abroad was made, the first World's Fair being then held in London. While on this visit the idea first occurred to him to make a garden of his own, modeled after those which are so well known upon the great private estates of England. Mr. Shaw returned in December, 1851; the mansion at Tower Grove had been finished in 1849, and the one on the corner of Seventh and Locust streets was then being built. After this time he was in St. Louis, with the exception of short summer vacations at the Atlantic coast or the northern lakes. Seemingly a man of leisure, he was really a very busy man for the next thirty years, and was never an idler until compelled to be.

In 1857 the late Dr. Engelmann, who was then in Europe, was commissioned by Mr. Shaw to examine botanical gardens and to obtain such suggestions as he might think of value. About this time a correspondence was begun with Sir William J. Hooker, Director of Kew Gardens, who wrote on August 10, 1857:

> Very few appendages to a garden of this kind are of more importance for instruction than a library and economic museum, and these gradually increase like a rolling snowball.

Accordingly, Mr. Shaw in 1858–9 erected a building for this purpose. The selection of books was entrusted largely to Dr. Engelmann in consultation with Hooker, Decaisne, Alexander Braun and others of his botanical friends. At the same time Dr. Engelmann urged upon Mr. Shaw the purchase of the herbarium of the recently deceased Professor Bernhardi, of Erfurth, Germany, which was offered at a very small price. Hooker wrote January 1, 1858:

> He [Engelmann] tells me of the herbarium of the late Dr. Bernhardi, of Erfurth, which he expects to buy for St. Louis. That ought to be a good commencement for the more scientific part of the establishment. . . . The state ought to feel that it owes you much for so much public spirit, and so well directed.

Mr. Shaw has told that he at one time planned a grand school of botany, with residences for the faculty, laboratories, etc., opposite the main gate; but he abandoned the project because of the advice of Dr. Asa Gray.

In 1866 Mr. Shaw secured the services of Mr. James Gurney from the Royal Botanical Gardens of London, whose practical experience and faithfulness contributed very largely to make the Garden and Tower Grove Park what they are to-day. Mr. Shaw, however, never abandoned his personal supervision, and he thus spent the last twenty-five years of his life perfecting what he had begun. Until the summer of 1885 he had not been out of St. Louis, except to drive out to dine with a friend, for about twenty years. At this time the hot weather caused a failure of his usual good health, and he went to northern Illinois and Wisconsin for some time. He returned much improved and resumed his accustomed avocations with renewed vigor.

On the twenty-fourth of July, 1889, he received numerous visitors who congratulated him upon the beginning of his ninetieth year. Although weak, he was able to meet them in the drawing-room, and his mind was as clear as ever. This, however, was his last public appearance. An attack of malaria resulted in his death on August 25. On Saturday, August 31, he was laid to rest in the mausoleum which had been already prepared in the midst of the garden which he had created—not only for himself, but for all succeeding generations.

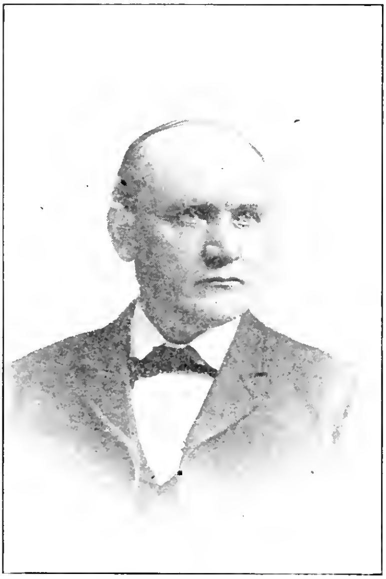
FIG. 17. MR. GEO. W. LETTERMAN.

Mr. G. W. Letterman is one of the few persons who have worked upon botany in the vicinity of St. Louis during their whole lifetime. Mr. Letterman has worked especially in Missouri, but is also very familiar with the plants of the region included in eastern and northern Texas, Louisiana, Arkansas and Indian Territory. He has accumulated a very large herbarium, in which the flora of St. Louis is represented probably better than in any other private herbarium.

George Washington Letterman,[22] the son of John and Charlotte (Blair) Letterman, was born near Bellefonte, Center County, Pennsylvania, of a family which had lived for three generations in Pennsylvania, his father being of Dutch, and his mother of Irish descent. From the public school he entered the State College in Center County, but left before graduation to join the Union Army, in which he enlisted as a private; serving until the end of the war he was mustered out of the service with the rank of captain of volunteers. After crossing the plains to New Mexico in 1866, he returned to Pennsylvania, and then going west again to Kansas, with the idea of becoming a farmer in that state, he finally, in 1869, settled in Allenton, Missouri, a railroad hamlet about

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[22] Sargent, C. S., "Silva of North America," 13: 79–80, 1902.

thirty miles west of St. Louis. Here Mr. Letterman taught in the public schools uninterruptedly for twenty years, and then for two years served as superintendent of schools in St. Louis County. Shortly after settling in Allenton Mr. Letterman met August Fendler, the botanist, who had a farm at this time in the neighborhood. This meeting with Fendler stimulated his interest in plants, especially in trees, and led to an acquaintance with Dr. Engelmann, for whom Letterman made large collections of plants in the neighborhood of Allenton, with many notes on the oaks and hickories. In 1880 he was appointed a special agent of the Census Department of the United States, to collect information about the trees and forests of Missouri, Arkansas, western Louisiana and eastern Texas, and later he was employed as an agent of the American Museum of Natural History in New York, to collect specimens of the trees of the same region for the Jesup collection of North American woods. The distribution of the trees of this region before Mr. Letterman's travels was little known, and much useful information concerning them was first gathered by him. Of his numerous discoveries species of *Vernonia, Poa* and *Stipa* commemorate the name of Letterman.

The above account is taken verbatim from Sargent's "Silva of North America," as it is the only authentic account of Mr. Letterman's life available. Mr. Letterman still lives at Allenton, Missouri, and is carrying on his botanical work. From the accounts of those in a position to know, his herbarium is very large, and at the present time probably contains as complete a representation of the St. Louis flora as any other, with the possible exception of the Eggert collection, which, however, can hardly surpass it. Mr. Letterman is connected with the local botanical societies, and is well known by the botanical workers of the city.

One man who has left an enduring impression upon botany, although his life work was along other lines, was Dr. Charles Valentine Riley.[23] Dr. Riley was born at Chelsea, London, September 18, 1843. His boyhood was spent at Walton-on-Thames, where he became acquainted with W. C. Hewitson, the author of a work on butterflies. This acquaintance undoubtedly turned his inclinations towards entomology. He studied for three years in the school at Dieppe and afterwards at Bonn. His teacher at the latter place urged him to study art at Paris, but this was not done. At the age of seventeen he emigrated to Illinois and when about twenty-one went to Chicago as reporter and editor for the *Prairie Farmer*. He was for six months in an Illinois regiment during the latter part of the Rebellion. He attained such success as an entomologist that he was made State Entomologist for Missouri in 1868, and he held this office until 1877, when he went to Washington in the government service. During this period he and his assistants, Miss Mary E. Murtfeldt and Mr. Otto Lugger, worked out two cases of the relation of insects to plants which are of more than ordinary interest.

In 1863 there were first noted in France the ravages of the Ameri-

[23] Howard, L. O., *Proc. Soc. Prom. Agric. Sci.*, 17: 108–112, 1896.

can *Phylloxera* upon the tender European varieties of grapes. These injuries became so serious that in 1872 the trouble was known not only in France, but in Portugal, Switzerland, Germany and England, and the entire grape and wine industry of Europe was threatened with annihilation. Riley became much interested in the problem of controlling the pest and finally hit upon the plan of grafting the susceptible European varieties upon roots of the resistant American species. This simple expedient undoubtedly saved the grape industry of Europe and also incidentally prevented a tremendous loss of money.

The second case was one of purely scientific value and interest. Dr. George Engelmann had noted that the character of the pollen of *Yucca* indicated that pollination of the flowers must be accomplished by some kind of an insect. Riley took up this hint and finally, with the aid of his assistants, discovered that the pollination was actually performed by the *Pronuba* and *Prodoxus* moths. This line of work was continued for twenty years, and a series of publications upon it issued at various times during this period.

Incidentally his work was of interest to botanists in many other cases, but these two seem especially noteworthy. He won an enviable reputation among entomologists the world over. He died the latter part of the year 1895.

Because of her botanical work, as well as her association with Dr. Riley in working out the pollination of *Yucca* and other problems, Miss Mary E. Murtfeldt deserves mention. In 1885 Professor S. M. Tracy, then of Columbia, Missouri, published a list[24] of the plants of the state. In this list one finds many species from the vicinity of St. Louis credited to "Murtfeldt" as their collector. These specimens were collected by Miss Murtfeldt not long before the publication of the "Tracy" list and are still in her possession, forming a collection of about 500 numbers. Miss Murtfeldt's first scientific work was in botanical lines, but this later changed to entomology, her botanical knowledge being indispensable in following out the life histories of new or little known insects upon their host plants. Many of her later botanical specimens are of much interest from the entomological standpoint and were prepared for that purpose alone. Miss Murtfeldt is well known among entomologists for her work, which has been mostly of this nature.

In 1874 Mr. Henry Eggert, as he was known, came to St. Louis, went into business, and began the study of the local flora and the formation of an herbarium which probably represented the flora of that vicinity at the time of his death, the best of any in existence. Eggert came to America from Prussia when about thirty years of age; he had already collected and studied the plants of different sections in Europe,

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[24] Tracy, S. M., "Flora of Missouri," *Mo. State Hort. Soc. Report* (Appendix), 1–106, 1885.

and his work about St. Louis seems to have been simply a continuation along similar lines to that already done in Europe. Although he lived in St. Louis and in later years in East St. Louis, he seems to have been somewhat of a hermit, and was not understood, or even comparatively well known, by his neighbors. He seems to have been an enthusiast upon botany, and his botanical collection was apparently his one luxury and hobby.

Heinrich Karl Daniel Eggert[25] was born March 3, 1841, in the town of Osterwieck, Prussia. He was educated at a seminary in Halberstadt, and became a teacher in the public schools of the neighboring city of Magdeburg. He early became interested in the study of plants, and before leaving Europe he had made botanical collections in the Harz Mountains and on short journeys to Kreuznach and in Bohemia. Dissatisfied with the small salary of a German school teacher, Eggert came to America in 1873, and for a few months worked on a farm in southern New York. From New York he went to St. Louis, where he remained for a number of years and then removed across the river to East St. Louis, where he lived the rest of his lifetime.

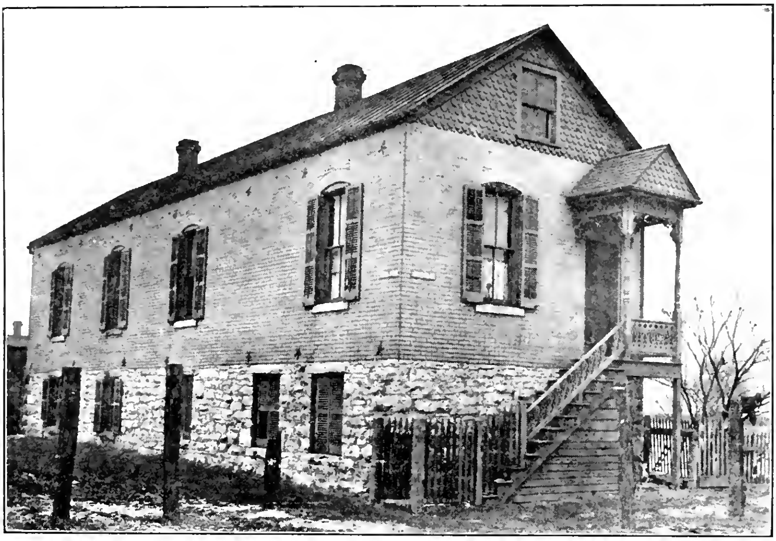

FIG. 18. THE EGGERT HOUSE IN EAST ST. LOUIS, ILLINOIS; practically as it was at the time of the death of Henry Eggert.

The first work which he seems to have taken up in St. Louis was that of carrying papers for the local press. He carried papers for about twenty years, handling both a morning and an evening one. He worked early and late, never sparing himself and always living by himself in a secluded manner. Comparatively few persons ever saw the in-

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[25] Sargent, C. S., "Silva of North America," 13: 51–52, 1902.

terior of his house, and still fewer were on really friendly terms with him, as we ordinarily use that phrase. While he had but little to do with his neighbors he never seems to have had any enemies.

Eggert's first start in making more money than usual was at the time of the great outbreak of the American *Phylloxera* in the vineyards of Europe, destroying immense numbers of the vines and threatening the entire wine and grape industry of Europe. It was finally discovered that the American native grapes might be used as stocks upon which to graft the more susceptible European varieties, so that a vine was obtained which had roots of the American resistant species with the top of some desirable but susceptible European species. This work resulted in an immense demand for the seed of some of our native species of grapes. Eggert's knowledge of botany led to his being recommended as a suitable person from whom to get these seeds. For at least two or three years he made a business of collecting and selling them to foreign countries. The business was quite remunerative and in the proper season he is said to have made several hundred dollars a month in this way. He seems to have kept up his carrying of papers at the same time. At first he carried them on his back, taking immense loads in a bag slung over his shoulder. As his business grew he bought a horse and wagon and still later he employed others, so that at one time he conducted a considerable business of this kind. He never relinquished his botanical work, and in early days he collected specimens for sale to botanists and for use in colleges and schools, thus making some little money. In later years his left arm and hand became affected with a partial paralysis which he attributed to his severe work in carrying such heavy weights of papers slung over that shoulder.

His money he invested in farms and similar property, and he succeeded in amassing considerable property. In his personal habits he was always very frugal, his only luxury seeming to have been his botanical collecting. In 1896 he sent to Germany for his nephew, August Eggert, and turned his greenhouses over to him to run. This nephew lived more or less intimately with him. Mr. Eggert was always of a peculiar disposition, apparently being constantly in fear of some attempt upon his life. He had hallucinations in which he thought every one had designs upon his life, and these became worse as he grew older. His mind was undoubtedly unbalanced, and on the night of April 18, 1904, he shot himself with a revolver.

As mentioned above, Eggert early learned botany and collected extensively all of his life. He collected assiduously all around St. Louis for a considerable distance, and his collection probably represented the flora of this district better and more completely than any other ever made. He also went on collecting trips to various parts of Missouri, Illinois, Arkansas, Alabama, Tennessee and Texas, and the southeastern states. He seemed to possess a genuine love for botany, and his determinations seem to have been, as a rule, correct beyond the ordinary. He was a charter member of the Engelmann Botanical Club, and was its first vice-president. He was also a member of the International Association of Botanists, and was made one of its vice-presidents.

Personallly, he seems to have had no enemies; he always remembered an injury, either real or fancied, and was unstinting in his expression of dislike for those who had in any way incurred his displeasure. His love of botany and his fine herbarium made him well known to the local botanists, yet he never seems to have been on really intimate terms with many of them. He was always ready to exchange specimens of rare plants or local species, and his herbarium was thus greatly enlarged by exchange from other countries as well as from all parts of the United States. During early days he collected specimens for the purpose of selling them, but as he grew older he could rarely be induced to sell his specimens, preferring to exchange.

His herbarium at his death was estimated to contain about 60,000 specimens, and was considered very valuable. It was acquired by the Missouri Botanical Garden, and is at present being incorporated with the herbarium of that institution as rapidly as possible. His herbarium is especially valuable for the reason that it was the basis of a local flora published by Eggert in 1891 under the title "Catalogue of the Phænogamous and Vascular Cryptogamous Plants of the Vicinity of St. Louis, Mo." His preface is characteristic and self-explanatory, so that it may well be given:

> Since[26] the publication of Mr. Geyer's catalogue of the Plants of Illinois and Missouri, about 1842, no other effort has been made to publish a list of plants growing in the vicinity of St. Louis but my own partial lists of species found in former years. I hope my present catalogue of Plants growing in a radius of about 40 miles around St. Louis will be welcome to botanists until a local flora is published.
>
> Since 1874 I have systematically looked over the ground in all directions, so that very few plants will have escaped my observation; but as I could only go out one day at a time, in places too far off from railroads, there still may be found something new. Railroads also will bring new immigrants from other regions when some of our own plants may have vanished, so that it will be a very important matter for later botanists to know what in former years was growing here. This idea mostly led me to have this catalogue printed.
>
> With the exception of a few plants reported to me by Mr. Letterman, of Allenton, Mo., all plants are collected by myself. The catalogue contains nearly 1,100 different species and varieties, so that St. Louis need not be ashamed of her flora.

This catalogue of Mr. Eggert's is by far the best and most nearly complete list of our plants which has yet appeared. Besides the above mentioned catalogue, a number of small lists of desiderata were dis-

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[26] Eggert, Henry, "Catalogue of the Phænogamous and Vascular Cryptogamous Plants in the Vicinity of St. Louis, Mo.," 1–16, 1891.

tributed to Eggert's correspondents for a number of years. Aside from these he published absolutely nothing, so far as now known. Exact localities were not given either in his lists or upon the labels accompanying his specimens, but he is known to have kept a note-book in which all such data were given. This note-book disappeared during the changes following his death, and thus much valuable and intimate knowledge of our flora was lost. As mentioned above, his entire herbarium is now in the possession of the Missouri Botanical Garden, where it will receive the best of care and will be accessible to all botanists desiring to use it.

One of the more recent collectors who have worked in and about St. Louis, especially upon the fleshy fungi, is Dr. N. M. Glatfelter.

Dr. Noah M. Glatfelter was born in York County, Pennsylvania, on November 28, 1837. He lived on a farm until he was seventeen years of age, when he began teaching school. He finished seven terms, and during the time attended successively the York County Academy, Lancaster County Normal School, and Franklin and Marshall College at Lancaster, Pa., for two thirds of the sophomore year. He then commenced the study of medicine with Dr. John L. Atlee, of Lancaster. In 1862 he attended the medical lectures at the University of Pennsylvania, and graduated from the same institution in 1864. He then received a commission from President Lincoln as Assistant Surgeon of United States Volunteers. In 1867 he left the army in Dakota territory. Ever since that time he has practised medicine in and near St. Louis.

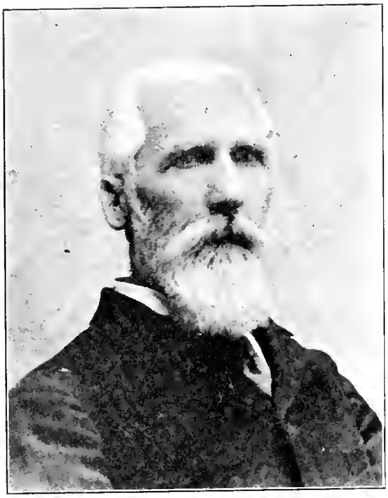

FIG. 19. DR. N. M. GLATFELTER; about 1900.

About 1889 Dr. Glatfelter commenced collecting the herbaceous plants in the vicinity of St. Louis and obtained specimens of most of the species of the district. This herbarium is still in the collector's possession. From 1892 to 1898 he gave special attention to the willows of St. Louis, and contributed papers on the venation of *Salix,* on *Salix* hybrids, on *Salix longipes* and on the relations between *Salix nigra* and *S. amygdaloides*.

In 1898 he became interested in the collection and study of the Hymenomycetes. This has led to the accumulation of about five hundred species, making quite an exhaustive collection of these fungi. This work is being continued and has already resulted in the discovery of a number of species new to science, several of which have been named in honor of their discoverer. This material has been submitted to Professor Chas. H. Peck, so it is authoritatively named.

In 1906 a list of this collection was published by the St. Louis Academy of Science.[27] The specimens are mostly in Dr. Glatfelter's private herbarium. Collecting has also been done in Pennsylvania in 1899, 1905 and 1906, and somewhat in other states. The herbaceous herbarium has been increased by exchanges, so that it numbers over 4,000 species. Dr. Glatfelter is a member of the local botanical societies and is still collecting the fleshy fungi, to which he is giving most of his attention.

The more recent botanical workers of St. Louis we find grouped into two distinct bodies; the staff of the Shaw School of Botany, and of the Missouri Botanical Garden, and the investigators of the Mississippi Valley Laboratory of the United States Department of Agriculture. In the former group, which has existed for the longer time, the following persons should be mentioned: Dr. William Trelease, director of the Missouri Botanical Garden since the death of Mr. Shaw, and also professor of botany in the Shaw School of Botany. Besides administering the affairs of these two institutions, and bringing them to their present development and efficiency, he has published many scientific papers; the earliest ones were concerned with fungi and various plant diseases; then the pollination of flowers was taken up; and of late years his work has been in the systematic revision of certain groups, such as the genera *Acer, Rumex, Yucca*, etc. Under his management the botanical garden has issued eighteen annual reports of scientific material, which have given that institution a name for scientific research, although it can hardly even yet be said to have fairly emerged from the preparatory stage of its development. Associated very closely with Doctor Trelease since 1894 is Mr. H. C. Irish, who has had general charge of the grounds, greenhouses and outdoor planting. Mr. Irish has published papers on horticultural subjects, including a scientific revision of the genus *Capsicum*, and of the "garden bean," and has in preparation another extensive paper along similar lines. Mr. C. H. Thompson has been connected with the garden for a number of years, and is engaged also upon scientific investigations. Dr. J. A. Harris, librarian of the garden, has published a number of scientific papers, and is engaged upon others, in the preparation of which the extensive and excellent library facilities of the garden are being fully employed. Others who have been connected with the garden staff, and who are now well known scientifically, are Dr. L. H. Pammel, Dr. H. J. Webber and

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[27] Glatfelter, N. M., "Preliminary List of Higher Fungi Collected in the Vicinity of St. Louis, Mo., from 1898 to 1905," *Trans. Acad. Sci. St. Louis*, 16: 33–94, 1906.

J. B. S. Norton, all of whom worked more or less upon the fungi of the locality while at the garden. Dr. S. M. Coulter, assistant professor of botany in the Shaw School of Botany, has, ever since coming to St. Louis, been working upon ecological problems.

The second group of botanists is a small one, of whom the following have been more or less intimately connected with the local work being carried upon the flora of the vicinity: Dr. Hermann von Schrenk, in charge of the Mississippi Valley Laboratory until its removal to Washington in 1907, has published a number of scientific papers dealing with the diseases of forest trees and of timber. Some of these were worked out from material collected around St. Louis, either partially or entirely. Dr. von Schrenk continues his work at St. Louis, having severed his relations with the United States Department of Agriculture upon the removal of the Mississippi Valley Laboratory from St. Louis to Washington. Drs. G. G. Hedgcock and Perley Spaulding, assistants of Dr. von Schrenk, were also engaged upon problems relating to the diseases of fruit and forest trees. All three have collected the fungi of the vicinity, and have been intimately connected with the botanical activities of the place.

Besides the above workers should be mentioned Mr. John Kellogg, long employed by the garden, who is very familiar with the local flora, and has a very good private herbarium; Dr. N. L. T. Nelson, who is collecting the mosses of the vicinity; Mr. H. M. T. Hus, who is collecting the algæ; and numbers of others who have collected in the locality at various times.

FIRE'S HAVOC A SENSELESS WASTE

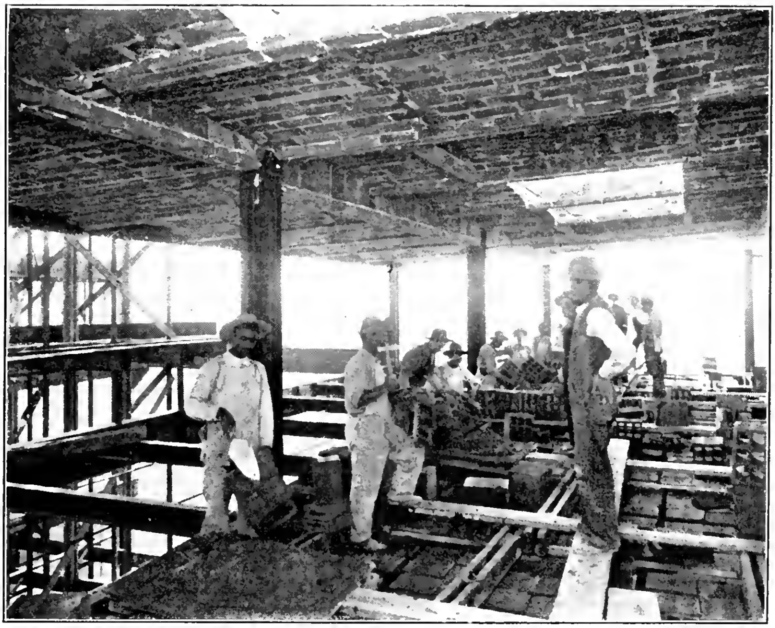
By F. W. FITZPATRICK
WASHINGTON, D. C.

WE have reason to be proud of the phenomenal growth of our American cities, the beauty of their buildings and the vast volume of building construction that is yearly carried on in the process of that growth. But a careful analysis shows us that that great volume of building is not *all* growth, but is, to a very great extent indeed, the replacing of buildings that have been destroyed by fire. And that destruction, a most senseless and cruel waste, has had a proportionate increase, year by year, far in excess of the pro rata of our new buildings or indeed of many other details of our rapid growth. In this country we deal in big figures and it would almost seem as if we were as proud of our appalling wastes as we are of our mammoth productions. At least one would judge so by the complacency with which we contemplate a drain upon our resources that would be deemed positively intolerable in any other country.

Statistics from all over the world for the year 1908 are now pretty nearly complete. Let us see what that year has meant in this fire matter. In the forty leading cities new buildings and repairs to old ones, building construction, reached a total value of $478,000,000 in that year, or a grand total in all the cities and towns of $510,000,000—the biggest year we ever had in our history, 1905–6 showed a total of $667,000,000. Now then, during the same period we permitted to be destroyed by fire buildings and contents to the value of $218,000,000. Incidentally, the reader will please remember that in most transactions where "losses" occur, those losses resolve themselves generally into transmutations or exchanges. In financial matters where one man loses the other gains, in more scientific affairs fuel, for instance, is consumed but produces steam, power. They say that nothing is utterly lost, but we also know that in this fire proposition nothing is left but ashes and smoke. It is not an exchange. The destruction of value is absolute for so far we have exceedingly little use for ashes, and smoke has not yet been turned into anything commercially or scientifically valuable. Add to the value of property destroyed the cost of maintaining fire departments, fire-fighting apparatus, high water pressure, city and private efforts at *stopping* fire when once it has started, something like $300,000,000. Then, in a further effort to recoup ourselves after fire has laid waste our property, we have gambled with the in-

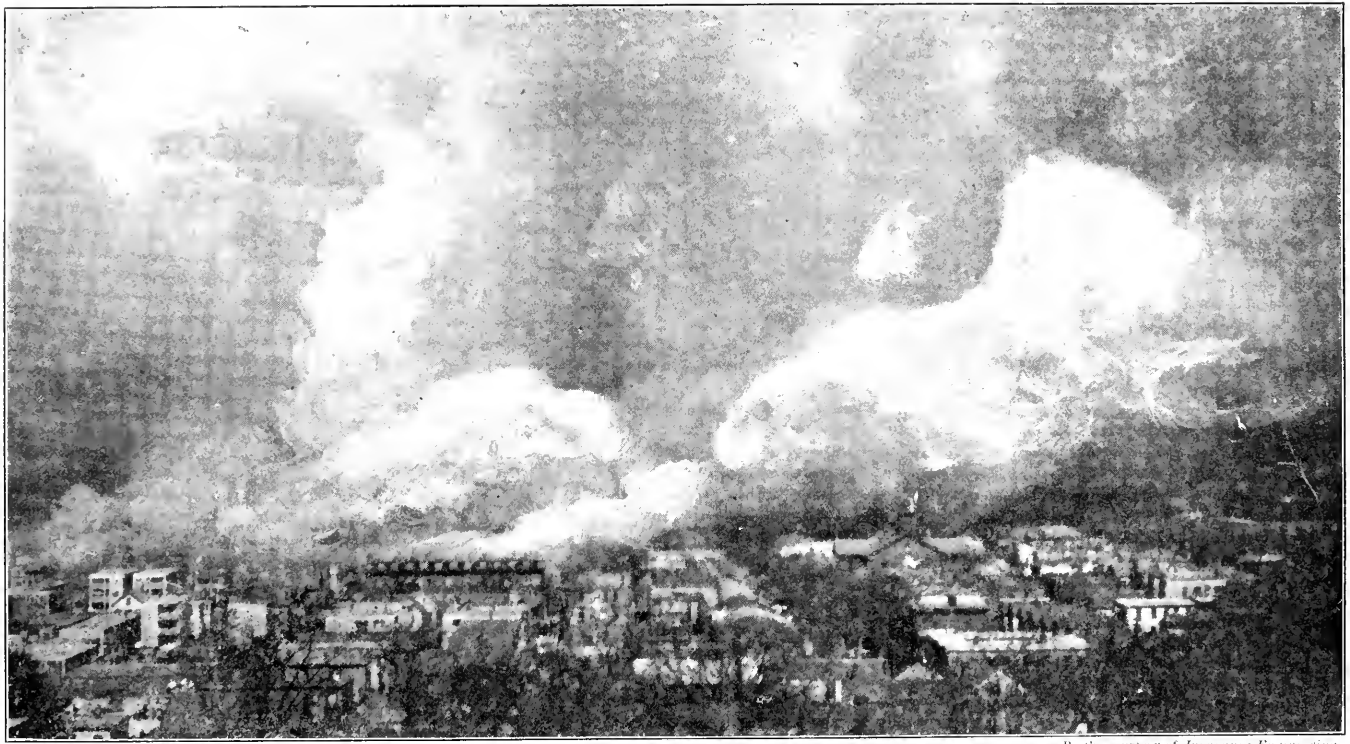
Fighting Fire with Dynamite at San Francisco.

surance companies in a bet that our buildings would burn. During the year we have paid those companies in fire-insurance premiums $316,000,000. They have paid us back in adjusted losses $135,000,000, so that the difference between those two sums, $181,000,000, is the amount we have paid those companies for the privilege of getting back a little over half of the value of the property we have permitted to be destroyed by fire. Applying the paid losses of $135,000,000 on the burned value of $218,000,000, the net loss in property value was $83,000,000, the cost of fire "protection" of all kinds was $300,000,000 and the amount we gave the insurance companies to guarantee us some reimbursement for our losses was $181,000,000, so that the total of destroyed values and incidental costs of fire for the year was $564,000,000. Compare this figure that we might call destruction with the new buildings added, $510,000,000, or what we might call production, and the result is not one of which we have any reason to be proud.



BUILDING THE FLOORS AND PROTECTING THE STEELWORK WITH HOLLOW FIREPROOFING TILE IN A MODERN SKYSCRAPER.

Eliminating the consideration of the cost of fire-fighting, we have destroyed in property values $1,258,000,000 worth in the past five years! Again eliminating all incidental expenses fire alone has cost us in 1908, $2.72 per capita. Compare that to the fire losses in European countries and you will realize how far behind them we are in fire-prevention. In France, Germany, Italy, Switzerland, Austria and



By the courtesy of *Insurance Engineering*

VIEW OF THE CHELSEA FIRE FROM THE MARINE HOSPITAL.

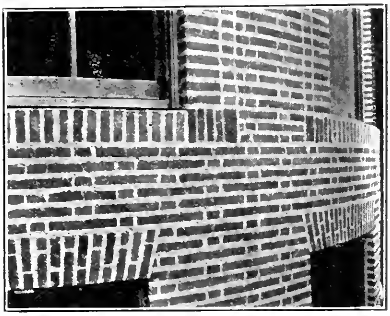
Denmark the general average is a trifle less than 33 cents per capita. In Italy it is as low as 12 cents and in Germany it has never been above 49 cents. In thirty of the principal foreign cities the average was 51 cents, while in 252 of our cities the average was $3.10! In New York City in 1908 there were 14,000 fires and the property loss amounted to $7,250,000, and the cost of maintaining the city fire department was $7,000,000; in St. Louis, there were 3,200 fires with a loss of $1,298,000, and the cost of the fire department was $1,018,000, and so our cities run with a general average of the cost of fire departments almost equalling the actual combustion of property. In Europe, Rome may be taken as a fair example, an average. There fire losses amounted to $56,000 in a year in 270 fires and the maintenance of its 200 firemen costs $50,000 and Rome is a city of 500,000 people, or nearly the size of St. Louis.

Let me add just one more comparison and then we will leave tabulations alone, for statistics are always more or less wearying. In this country in January of 1908 the total amount of building and repairs done scarcely reached $16,000,000: during that same month fire destroyed $24,000,000 worth of property.

Surely we have had figures enough to clearly establish and to firmly impress even the layman that fire can be said literally "to be eating at the very vitals" of our economic structure. Many causes have contributed to this deplorable condition. One is that our people are naturally reckless and careless and build as they do much else, merely for the moment, temporarily. Then, too, until very recently our lumber supply has seemed inexhaustible and it was the material with which buildings could be erected with greatest rapidity and least initial cost. The pioneer couldn't be expected to haul brick and steel into the wilderness when he had trees all about him from which he could fashion his rude habitation. Pioneer settlements grew into villages and the villages into cities and the habit of building of wood stuck to them. Why, even last year, with the price of lumber a hundred per cent. higher than it was ten years ago and with incombustible materials available everywhere and at low cost we still built 61 per cent. of the year's construction of wood. In the older communities, in Europe, they have got well over their pioneerdom and lumber has never been so plentiful as with us and the authorities have had more forethought and realized the necessity of better construction so that the general average of the buildings in cities, towns and villages is infinitely less inflammable than is the average here. But from that it must not be deduced that the science of building is carried to greater perfection there than here. That seems an anomalous condition but it's a fact nevertheless that our architects and engineers know a great deal more about fire-proof construction and practise it to a far higher degree of perfection than do the architects and engineers of Europe. They really have nothing to compare with our superior buildings. Take, for instance, the Singer Tower in New York and regardless of its height, there is nothing in Europe to compare with it in the way of fire-resisting qualities. The trouble with us is that there are so few of those buildings. We have something like 12,000,000 structures in the country, but of that vast number there are but 8,000 in which even the slightest effort has been made at fire-prevention! It is our average construction that is so poor and that makes such a bad showing compared with Europe. You can readily see that in a city composed of buildings that are not fire-proof, but that are comparatively incombustible, the fire hazard is much less than it is in a city of fire-traps with a few perfect buildings scattered here and there. And, too, in order to resist fire those fire-proof buildings have to be superlatively perfect because there is so much fuel all around them that a fire attack against them is vigorous in the extreme. In the European cities the big and important buildings need not to be so perfectly constructed because the danger of fire from within is always the minimum and the danger of fire from without is not very great on account of the superior general quality of construction. There it is seldom that a fire gets beyond the building in which it originates. Here, in spite of our splendid fire departments—and there are none superior to them, for none have the practise and the experience they have—fires frequently extend to neighboring buildings, entire blocks and indeed whole sections of cities.

Municipalities, states and even the country at large are beginning to realize the gravity of this fire waste and that something drastic has to be done towards fire-prevention. The great trouble is that whatever we may do now can simply be an abstaining from adding fresh fuel to burn because we have received such a heritage of combustible buildings that it will be yet many years before those old fire-traps will have all been destroyed or torn down to be replaced with better buildings. But a beginning has to be made some time and most of our cities have so revamped their building regulations that at least within certain districts nothing of an inflammable nature may not be erected. But that is not enough, because immediately outside of those districts we are permitting fire-trap construction that, in turn, will be the inheritance of our successors and will be in congested districts and prove almost insuperable barriers to real progress. The thing to do is to absolutely prohibit inflammable construction, the use of wood, in the structural parts of buildings erected *anywhere* within the jurisdiction of a city.

Many may deem this a great hardship upon the poor man and that it would be almost prohibitive in cost. That is a most popular mistake. The first cost of a fire-proof building is but 12 per cent. or 15 per cent. more than that of ordinary construction. But, considering the difference in repairs, the longevity of the better building and the lessened, if any, insurance that need be carried, inside of four or five years that difference is wiped out and, as a matter of fact, the best construction is an actual economy, for in no case does the interest on the added cost of good construction amount to anything like the insurance premiums, the wear and tear and deterioration of the ordinary or allegedly cheap building. The only man who profits by the so-called ordinary or cheap building is the Buddenseick, the speculative builder whose business it is to put up the flimsiest kind of a contraption, paint it gaudily and sell it at a fat profit to the easily gulled individual who believes in buying ready-made houses.



Artistic Bricklaying.
Indestructible by fire; as effective as granite or marble and less costly.

The space assigned me will hardly permit our going very extensively into the minutiæ of fire-proof construction. Suffice it to say that in general terms it means the avoidance of anything combustible. But farther than that it is also well to remember that many materials that are in themselves incombustible, non-inflammable, are most seriously damageable, nevertheless, by flame or great heat. Iron, for instance, can not burn but subjected to heat it will twist and contort and in column form, as an illustration, it will collapse to the utter destruction of whatever it is supporting. So that many materials have in turn to be protected from fire though they will not themselves burn. Many people imagine that stone represents the very epitome of safe and permanent construction, yet all granites, marbles, sand and limestones spall and go to pieces under severe fire tests. My idea of a perfectly fire-proof building, therefore, is one whose exterior walls are of undamageable material, brick and terra-cotta, products that have gone

An Insufficiently protected Steel Column after a Fire.

through intense heat in their process of manufacture. The internal framing, the skeleton, is of steel, thoroughly protected from fire by brick or hollow tile; the partitions and floors are also of tile; the elevators and stairways are enclosed and with automatically closing doors at every story so that each story is a unit by itself, virtually a separate building. This is all-important. Fire's tendency is ever upward. Make it impossible for fire to travel from story to story and you have cut down your fire possibilities 90 per cent. And the same thing applies to each story. These should be so partitioned as to form as small

FIRE'S INGRESS *via* THE WINDOW ROUTE.

units as possible. Fire can then do damage only in some small space in which it originates. The whole secret of fire-fighting is this isolation, this keeping of fire within the narrowest possible confines, where it can readily be extinguished and by any employee of a building without having to call out the fire department. Further, my perfect building would have all of its exposed windows or narrow alleys and streets wire glazed in metal sash. What is the use of stout brick walls if you provide openings for fire every few feet and offer no greater barrier in those openings than wooden sash and sheet glass? Forty-four per cent. of our entire fire loss is attributable to this lack of proper window protection. In San Francisco, nearly all the loss was traceable to that same cause, because after the earthquake fires only originated in a comparatively few buildings but spread from one to the other via the window route. My interior decorations would be of marble or metal, or even plain plaster tastily ornamented in color, anything rather than the heavy wooden wainscoting, wooden floors, beamed ceilings and all that sort of thing that means just that much well-oiled fuel or rather kindling for a fire. Such is a really fire-proof building. It is a type that has proved its value time and time and again. It is nothing new and untried; it is not a mere theory. The great trouble has been, however, that some one item or other has been neglected in our existing so-called fire-proof buildings. In one, the windows are unprotected, though everything else is well done; in another the elevator wells are open, some one thing that vitiates the whole, for, remember, that like a chain, whose strength is equal only to its weakest link, so is a "fire-proof" building only thoroughly fire-proof if everything about it is properly done. You can not have half-fire-proof or semi-fire-proof. Those are misnomers.

Therefore, it is imperative that our authorities should demand good, incombustible construction. Left to their own volition it would be years before the people would build that way. It has to be made compulsory. The community must legislate for its safety and against the selfish or ignorant interests of the individual. But it may help the individual nevertheless by making it directly advantageous to him to build properly. Supposing even that the regulations do not exact fire-proof construction everywhere, taxes should be so arranged that a maximum rate should be assessed against inferior, highly combustible buildings. It is for their protection that the city has to maintain expensive fire departments and fire-fighting media; were it not for those buildings such expense would be unnecessary. It is nothing but right, consequently, that the owners of those buildings should pay their full pro rata of that charge. The rate upon first-class fire-proof construction should be the very minimum because those buildings require the least of that protection and their owners should not be made to pay as

DAMAGE BY WATER—$1,000 a minute while these three nozzles are being played upon the contents of a warehouse.

SEARCHING FOR THE DEAD AFTER A FIRE.

INEFFECTIVE FIREPROOFING.

much for it as are others. This would be but equitable in the first place and in the second place would encourage men to replace their combustible contraptions with better buildings. Next and immediately necessary the authorities should conspicuously label every building of public or semi-public nature, just as to its class of construction, "fire-proof," "ordinary," "dangerous." As it is now, the term "fire-proof" is cruelly abused. It is applied where there is not the slightest foundation for its use and is made the means of obtaining tenants and occupants under false pretenses. A man with "dangerous" affixed to his building would have difficulty in renting it and that would be a powerful incentive to him to at least make the building better if he did not absolutely eliminate it and build correctly. Then we should have the same municipal regulations that they have in most European cities relating to "neighboring liability." Here we have a selfish way of taking care of ourselves and letting the other man shift. There they make you responsible for any damage to your neighbors' premises or property that may result from a fire on your premises caused by your or your agents' negligence or carelessness. It makes people wondrously careful in handling their ashes, waste paper, etc. These neighboring damages are always collectible at law in Europe and the regulation is one of the most effective of fire-preventative measures.

These are not heroic or revolutionary methods and yet, wherever applied, they would work marvels in the way of bettering conditions There is too much apathy in this fire matter and the authorities who know what it really means are fearful of applying the restrictions that are needed because, forsooth, some of these might too nearly touch powerful constituents or friends. We may only hope to attain the desired ends by forcing these authorities to do what is right via the pressure of public opinion. It is passing strange how those things run, but interesting withal to find that in all reforms the masses have to be compelled to do certain things by authority and the authorities have in turn to be compelled to apply these compulsory measures by the weight of public opinion: public opinion in turn is molded, created by printers' ink and I know of no cause that deserves better at the hands of the press than does this one of *fire-prevention.*

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THE SKY-LINE OF NEW YORK CITY.
The highest and best-constructed buildings in the world.

THE WORLD'S ANNUAL METAL CROP

By THEO. F. VAN WAGENEN, E.M.
ZACATECAS, MEXICO

SOME one has characterized the present as the "age of metals." There are at least fifty-nine of these useful substances known to the chemist of to-day, yet if the average well-educated man was asked to name them, it is doubtful if he could enumerate more than a score. In that far distant period called by the archeologists the "dawn of history" (say 8,000 to 10,000 years ago), only four appear to have been recognized, viz., copper, tin, gold and silver. Sometime later, iron, lead and mercury were added to the list. These seven constituted the metallic stock in trade of the ancients, and of the moderns for the first thousand years of the Christian era. In the opinion of most historians, copper, as the metal that is found most abundantly in the native or pure state, was the first to attract the attention of primitive man, and it is likely that tin was recognized very soon thereafter, for the latter, though far from abundant, and never existing naturally in the metallic state, yet occurs under conditions where it would be easily noted by its weight as a substance very different from ordinary stone, and in a chemical combination from which it can be smelted by the simplest of fire processes. Moreover, the greatest tin-producing district in the world lies in a part of the globe that has been inhabited from most ancient times. Both copper and tin are alone too soft to be utilized as weapons or tools, and humanity at a very early period in the progress of civilization learned to produce, by combining the two, that most serviceable alloy we know as "bronze," which can be forged and tempered to a keen edge and point, and which is so resistant to the attacks of air and water that great numbers of the implements made by the ancient smiths are preserved in the museums of the present day. Gold and silver were doubtless recognized as separate entities at a very early date, and their rarity and beauty set them apart at once as suitable measures of the value of other things. It is thought that iron, though the most abundant of all the common metals, did not come into general use until 1500 or 1000 B.C. For a long time lead was regarded as another form of tin. It does not occur in a metallic condition in nature, only one of its ores (cerrusite) is easily smelted, and most of them are associated with ores of antimony, arsenic and zinc, from which it is separable only with considerable skill. Mercury, on the other hand, comes from its ore with much ease, but it was a puzzle to the ancients, who called it "liquid or live silver" (whence our modern name, quicksilver), and they found but little use for it. Zinc was also one of the mysteries of the olden times. The Greeks and Romans knew of it as a troublesome impurity, often associated with lead ores, and in some way the very desirable alloy now called "brass," which is composed of tin and zinc, was discovered and produced by them to a limited extent, but the metal zinc remained unknown.

Through medieval times practically no progress was made in a knowledge of the metals. The science of chemistry was unknown, but its precursor, alchemy, flourished. The alchemists recognized many of the natural substances that are now known as ores of the metals, but were unable, except by accident, to decompose them. However, about the year 1450, antimony and bismuth became articles of commerce, and in 1520 pure zinc was produced, though it did not come on the market in any quantity until 1743. In 1694 arsenic was isolated and recognized. Thus, up to a little more than 200 years ago, the world knew of but eleven of the metals, and of these, arsenic and antimony are not now regarded as such, being classed as semi-metals.

Chemistry, as a science, began to arise during the eighteenth century, as a result mainly of the perfection of the laboratory balance to a point where delicate operations in weighing could be carried on. In this period the list of the metals was doubled by the discovery of cobalt and platinum in 1735–6, of nickel in 1751, of manganese in 1774, of tungsten and molybdenum in 1781, of titanium, uranium and zirconium in 1789, and of chromium and yttrium in 1792. All of these except zirconium and yttrium are now fairly familiar names to us, but none of them were produced in any quantity, or put to any commercial use as metals, for a long time after their discovery. Platinum for a century was merely a curiosity. Certain compounds of cobalt and of uranium found considerable use in the ceramic arts, and of chromium and manganese in the laboratory as reagents, in the crude chemical research of the day. But with the opening of the ninteenth century, and the advance of chemistry to the condition of an exact science, the metal elements began to come to light. Cerium, iridium, osmium, palladium, rhodium and tantalum became known in 1804; in 1807 potassium and sodium were recognized; in 1808 barium, calcium, magnesium and strontium, and in 1817 cadmium and lithium. Between 1828–1830 aluminum, glucium, thorium and vanadium were added to the list, and in 1839 lanthanum. Then came didymium, erbium, terbium, columbium and ruthenium in the five years between 1842 and 1846. In the sixties cæsium, indium, rubidium and thallium were discovered; in the seventies gallium; in the eighties germanium, and since then the chemists have added gadolineum, scandium, samarium, thulium, ytterbium, and finally radium.

The most of these are as yet merely names to the general public, and some are certain to remain no more than chemical curiosities for years to come. There are good reasons to believe, moreover, that the list is still incomplete. But of the fifty-nine now known, eleven, aluminum, copper, gold, iron, lead, nickel, mercury, platinum, silver, tin and zinc, are, as metals, among the staple articles of commerce, which are being produced in large and ever increasing quantities, as the demand grows; while another list of six (manganese, tungsten, molybdenum, titanium, chromium and vanadium) are market staples in the form of alloys with iron, being largely used in the production of certain brands of steel. These are known in the trade as the ferrometals. Again, there are six more (bismuth, arsenic, cobalt, uranium, thorium and cadmium) that are regularly produced, but not in the metallic state, for use mainly in the ceramic and electrical arts. Finally are iridium, osmium and palladium which find employment to a small but steadily increasing extent among makers of delicate instruments and tools of precision; tantalum, of which the electricians are now making incandescent light filaments, and magnesium, which for a number of years has been used by the photographers in the production of flash light. Thus nearly half of the total list may be said to be already among the indispensables of civilization, and already several of the remainder are under consideration by scientists, engineers and inventors—notably potassium, sodium and calcium—on account of the qualities they possess. Lithium, the featherweight of the metallic family, which will float in water, and has only one fifth the weight of aluminum, may before long be commandeered by the aeronauts, if a way can be found to protect it from the corroding action of air and water, while rubidium, that is as soft as fresh putty or wax at ordinary temperatures, zirconium, that possesses many of the qualities of thorium, and ruthenium, that is extremely infusible, are all certain to fill a want in the arts before long. In fact, each of the remaining known metals appears to possess some inherent and exclusive quality that will sooner or later be needed in our complex civilization. The most of those that are not yet exploited occur apparently in very small quantities in the crust of the earth, as, for instance, the last discovered, radium, which is so rare that but a few grains can be obtained from many tons of its ore. Yet it is one of the surprising facts of recent years that as soon as one of these rare metals is proved to be of real use to humanity, new sources of supply have quickly been found. We know little as yet as to the capacity of the wonderful storehouse we live upon. Nature seems to have provided a substance for every conceivable want of mankind, and beyond question, some of these substances that appear now to be useless are merely in reserve for wants not yet developed, while others that apparently are so scarce as to be of no practicable use, even if they had desirable properties, have only to be searched for, to be found in sufficient quantity for our needs.

Returning to the eleven well-known true metals, viz., aluminum, copper, gold, iron, lead, mercury, nickel, platinum, silver, tin and zinc, wonderful progress has been made during recent years in the matter of their production. Few of us appreciate the extent to which we are absolutely dependent on some of these substances which, a generation ago, were so rare. It is quite impossible now to conceive of a metalless civilization, or one in which they were so costly as to be practically unavailable for the ordinary affairs and circumstances of life. In the home, the office, the factory and the club they confront us everywhere. Upon the person of a day laborer ordinarily clothed, half of the list will usually be found, while in the home of the average well-to-do citizen every one, except perhaps platinum, will exist in more or less abundance. It will be both interesting and instructive to note just what amounts of these metals have been taken from the crust of the globe during recent years, for the benefit of our modern civilization.

Aluminum

This metal began to appear on the market as a costly curiosity, in 1888, just twenty years ago, commanding a price of $5 per pound, and the total world's output for that year did not exceed 50 tons. By the end of the century, however, the annual production had increased to nearly 5,000 tons, while the price had fallen to $1.50 per pound. Since then there has been a steady increase of output until during 1906 it amounted to about 20,000 tons, while the price had fallen to 35 cents, causing the metal to be available in so many ways and forms that the civilized world would now find very great difficulty in getting along without it. But, remarkable as has been this growth, it is as nothing to what may be expected in the near future. For aluminum is the most abundant of all the metals, existing in such enormous quantity in the crust of the earth, and in deposits so accessible and so easily mined, that it is certain to become, before another century has passed, and as soon as its metallurgy has been perfected, the rival and supplanter of iron. Every clay bank and slate quarry is a high-grade mine of the metal, only we have not yet learned how to extract it cheaply from these ores. Innumerable other rocks and formations contain it in various quantities. A well-known geologist has recently calculated that 8.13 per cent. of the earth's crust is aluminum, against 4.71 per cent. for iron, and less than one tenth of one per cent. for copper. Bulk for bulk, aluminum has one third the weight of iron. In tensile strength it is almost the equivalent of cast iron, though far inferior in that respect to steel. Yet the metallurgists are rapidly learning how to increase its strength by alloying with it other metals, and when it can be produced at a price not more than two or three times that of iron, it will certainly replace it very extensively. For it is far more ductile and malleable, it melts at half the temperature, and so may be cut or forged into bars, sheets and tubes at much less cost; it is practically unalterable in the air or water, while iron and steel disappear in rust in a very few years, unless very carefully protected by paint or grease or cement. As yet there is but one ore from which the metal can be produced with reasonable economy, the mineral known as bauxite, which has been found at only a few places, and in masses of comparatively small extent. The rate at which the demand for the metal is now growing will result in their exhaustion in a few years. The great metallurgical problem of the day, therefore, is to devise a means for the extraction of aluminum cheaply from its most abundant ore, ordinary clay. This problem is perhaps on the verge of solution. In another decade we are almost certain to see the metal a staple on the markets of the world at not to exceed five to ten cents per pound. When that day arrives a revolution will have occurred in the industries that it is difficult now to apprehend.

COPPER

Accurate statistics of the world's output of copper do not go back much further than the year 1879, when the amount was 170,199 tons. But fairly close approximations have been made for many previous years, and from these it appears that in 1856 the production throughout the world was about 47,300 tons. In 1906 it amounted to 786,794 tons. This is a marvelous increase in the case of a metal that is yet used as a coin by more than half the population of the globe. That the annual product now should be nearly seventeen times what it was about half a century ago, while at the same time the price should be less, explains why civilized nations have abandoned its use as a coin and for ornamentation, and indicates that modern man has acquired much greater facility than his immediate ancestors in extracting it from its ores, which are by no means abundant, nor easy to work. Those of us who have reached middle age can easily remember when a copper kettle was almost a family heirloom, to be kept under lock and key when not in actual use, and whose burnished sides and interior were the pride of the housewife. Nor in those days did we refer disrespectfully to pennies and cents as "chicken feed."

GOLD AND SILVER

The story of the two money metals is much the same as that of copper. A half century ago we used to talk of their production in terms of Troy ounces. During the eighties the kilogram (2.2 lbs.) began to be used as a more convenient unit, and now that has become entirely too small for silver, while many statisticians are using the 2,000-lb. ton for both metals. A ton of gold would make a little cube measuring about 14½ inches along its edges, and of silver, one of 17¼ inches. Measure these off on your desk ruler and it will become apparent into what small packages nature can pack her valuables if she has a mind to, for the golden cube will represent $602,861.22, while that of silver, at the price of 55 cents per ounce, will be worth $16,041.30. Now, in 1850, just before California and Australia began to produce the former metal in quantity, the world's annual crop of gold was about 60 tons, which could all be stacked away in a small bank vault, having a floor space four feet square and a height of six and one half feet—a mere closet. But in 1906 the crop amounted to 675 tons, more than ten times as much, and to accommodate it would require a vault of the same height, but with a floor space of twelve by fifteen feet—quite a good-sized room. As to silver, in the fifty-six years that have elapsed since 1850, the world's annual production has grown from about 975 to 6,360 tons. Carefully piled up in cubes this mass of the white metal would nearly fill up a room 100 feet long, 20 feet wide and 10 feet high.

Iron

In iron, the metal which is at the basis of the civilization of the day, the record is, if possible, even more remarkable. Reasonably accurate statistics of the world's production do not go back of the year 1865, when it amounted to 10,009,632 tons. In 1906 the output was 64,983,481 tons, showing an increase of nearly 650 per cent. in the forty years. Such figures are not easily grasped by the mind, but let us make the effort. Metallic iron weighs seven and a half times as much as an equal bulk of water. A cubic foot of water will weigh in round figures 62 pounds, and consequently one of iron will tip the beam at 465 pounds. This means that a ton of metal will contain a little more than four and a quarter cubic feet, and that a cube of it measuring about nineteen and a half inches along its edges will weigh a ton. Hence, the output of the year 1906, if put in the form of a solid cube, would contain 279,429,000 cubic feet, and would measure along its edges nearly 650 feet. A city block in New York measures, say, 250 by 500 feet, and its area is about 125,000 square feet, or roughly, three acres. Ten such blocks would be completely covered to the depth of 220 feet by the world's output of iron during the year 1906. This would be the equivalent in dimensions of an eighteen story building, completely covering a thirty-acre tract of land in the metropolis of America.

But to gain even a more striking impression of what the metal is to modern man, let us figure up the total production of the iron mines of the world during the last eventful forty years. In round numbers, it amounts to over six hundred million tons. Such a mass will measure up nearly twenty-six billion cubic feet. Put this into the form of a pyramid, with a base ten thousand feet square (about twenty-three hundred acres) and its height would be nearly eight hundred feet. Or, cut down the base to dimensions of a five thousand foot square (say sixty acres) and the structure would be nearly two thirds of a mile high. It may not be so difficult then to agree with the iron producers who claim that another half century of such strenuous civilization as the last one will serve to exhaust all the known great iron deposits of the world. Who of the generation that saw the Civil War would have imagined such an expansion of an industry that was then but lightly regarded even by economists? It is indeed high time for the chemists and metallurgists of the day to redouble their efforts to solve the problem of the cheap production of aluminum, for in that direction only does there seem to be an escape from the dilemma of a world unable to procure the common metal it needs, if its civilization is to continue.

Lead

In the case of lead we come down to more ordinary figures, yet none the less surprising when the services the metal gives us, by reason of its peculiar qualities, are considered. Without lead, no paint, no shot or bullets, no flexible piping. These are the three principal uses to which it is put in these days, and more than half of the annual crop of the mines becomes paint, and is employed to protect and improve the appearance of the structures that man raises to live, and to transact his business in. In 1885 the world turned out 391,542 tons of the metal. Lead is a dense and heavy substance, and it only requires a cube measuring a short seventeen inches along its edges to weigh a ton. Even so, the production of the year 1885 would make a mass covering a quarter of an acre of ground, and standing nearly one hundred and ten feet high. But when the year 1906 closed, and its doings were figured out by the statisticians, it was found that the lead mines of the world had turned out in that twelve months nearly three times as much as they had in 1885. To be accurate, the crop amounted to 1,061,533 tons. This mass of metal would make a pyramid with a base one hundred and fifty feet square, and rising nine hundred feet into the air. An increase of 300 per cent. in twenty years indicates an enormous growth in the demand for paint and putty, to say nothing of the consumption in the way of ammunition and piping.

Mercury

Mercury is the one degenerate in the family of the metals. Between 1850 and 1860 it was tremendously in demand by the miners of Australia and California, who were gathering their golden harvest with its aid, and in the two succeeding decades the silver miner also impressed it extensively into his service. But as the various great precious-metal mining districts of the world became connected with fuel and labor centers by rail, the smelting industry arose and gradually supplanted most of the amalgamation process in which quicksilver was the prime factor, and so the demand for it slowly declined. The largest recorded yield occurred in the year 1877, when the output amounted to 5,308 tons. In 1906 the world's production was only 3,964 tons. For many years now the silver miner has given up its use almost altogether, but the Alaskan placer miner must still have it, and there is yet a considerable consumption in those gold districts of Africa and Australia, where smelters do not exist, and even in our own west, at isolated or very low grade mines. At present the principal demand is for the manufacture of mirrors, and certain scientific instruments like thermometers and barometers. There is good reason to believe that there yet remains, undiscovered, in Asia, Africa and South America, one or more great gold placer regions. When these come to light the market for mercury will revive, and remain active until the new fields are exhausted. There is no lack of its ores in the crust of the earth. The metal has been produced in Spain for at least three millenniums; the California deposits are far from being exhausted, though they have been worked more energetically in the last fifty or sixty years than the Spanish deposits since their discovery, and the great mines of Huancavelica in Peru have hardly been touched. So when the demand again arises, mother earth is prepared to meet the drafts of her children, as usual.

Nickel

Fifty years ago this metal was practically unknown, except to the scientist. Its successful production as an article of commerce began in the United States about 1863, when it was detected in some copper ore coming from the Lancaster Gap Mine in Pennsylvania. For the next ten years, practically the entire world's output came from this mine. At its best, however, the yield never exceeded 100 tons per year, the metal commanding a price of $2.50 to $3 per pound, which of course severely restricted its use. In 1867 one of its ores was found in comparative abundance in the island of New Caledonia, a French possession, lying to the northeast of Australia, and commercial production from there began about 1874. In 1880 the metal was discovered in copper ores coming from Sudbury district, Canada, on the north shore of Lake Huron, and by 1886, a production began which has since steadily increased until at the present time two thirds of the annual world's crop of the metal comes from the later locality.

Finally, there is a small amount produced annually in Sweden and Norway. The total world's output in 1906 was in the vicinity of 19,000 tons. The largest use to which it is now put is in the manufacture of an alloy with iron which is particularly hard and tough, and hence suitable for armor plate. After that comes nickel coinage and plating. The metal has excellent qualifications for these latter purposes. It will not corrode or blacken under ordinary atmospheric conditions, it takes a high polish, and its soft white luster, with a faint tinge of yellow in it, is exceptionally pleasing to the eye. The modern world has a genuine need of nickel, and so the production will increase, but it is never likely to become as common a metal in the arts as copper or lead or zinc.

Platinum

The heaviest of all the metals is also the rarest of those that have become staple articles of commerce. It required nearly seventy-five years after its discovery for mankind to find uses for it. Then its extreme resistance to heat, and to the action of acids, commended it to the chemist, and later to the electrician. It began to come into the market in small quantities in 1824, from the region where it was first found—the western foothills of the Andes in the republic of Colombia. Almost simultaneously it was found in the Ural Mountains of Russia. The Colombian region has never been exploited or worked regularly, owing to the unsettled political conditions of the country, and it is figured that up to date not over 25 tons altogether of South American origin have been produced, practically all of which was gathered by natives in a desultory way. The Russian field has been operated regularly since its discovery, but with little enterprise or judgment or science. The metal has also been found in small quantities associated with gold in the auriferous gravel deposits of the Pacific coast of our own country. But up to the end of 1907 not more than 160 tons altogether of platinum had been produced throughout the world since its discovery, in spite of its rapidly increasing price, for it is now worth, weight for weight, about 25 per cent. more than gold. It is a real commercial misfortune that the two localities where it exists in such comparative abundance, and from which it could be produced in quantity, are under the control of nationalities so backward in social conditions and general civilization, that capital and engineering talent hesitate to take the risks involved in the illiberal laws and disturbed conditions that prevail. The metal occurs in nature generally in the pure or native state, and in the condition of grains, nuggets and dust disseminated throughout deposits of gravel, from which it is very easily recovered by methods similar to those employed in operating gold-bearing placer mines.

TIN

The story of tin is particularly interesting because it illustrates (perhaps better than that of any other metal) the interdependence of the elements of modern civilization. In 1862, which is about as far back as accurate statistics of its production go, the world's annual output was roughly 22,000 tons, of which about half came from Cornwall, and the balance in small and scattered amounts from Germany, Austria, South America, Mexico and the East Indies. In 1906 the crop amounted to nearly 109,000 tons, showing an advance of almost 500 per cent. in 45 years. When we investigate the uses to which the metal is put, we find that previous to our Civil War about all the need the world had for tin was for the manufacture of cooking and kitchen utensils, and for roofing. Now, however, nine tenths of the demand is caused by the canned food industries, and those connected with the distribution of mineral oils. Tin roofs are completely out of fashion, and aluminum is rapidly becoming the favorite kitchen metal. But the tin can, made of plated sheet iron, is the vehicle in which kerosene has traveled to every part of the inhabited globe, and which has made it possible for the fisherman, the stockman, the farmer and the horticulturist to deliver their products in a fresh and edible condition wherever there are people who want them. It is an interesting fact that quite three quarters of the annual crop of tin now comes from the East Indies, and is gathered by Chinamen and Malays. The region is probably the most ancient mining district in the world. Tin has been coming from there in small quantities for at least 5,000 years, ever since the beginning of the bronze age of the archeologists, and the world is only now beginning to appreciate the extent and value of the field. More than fifty per cent. of this old world product finds its market in the United States, where it is converted into millions of cans of all kinds, from the familiar five-gallon receptacle in which the Standard Oil people pack their product, down to the diminutive sardine can of the picnicker. When these are filled and sealed they start on their travels, and in a few brief months—or years at the outside—the neat vessels are scattered throughout the world from the equator to the poles, over the plains and deserts and through the mountains. Vast numbers of the larger sizes are doing duty as water pails everywhere, while the remainder become vagrants and strays in the refuse piles that everywhere mark the paths or dwelling places of man. Thus the metal, gathered with toil and danger by the patient and stolid oriental, is by the strenuous and impatient occidental put to a use which almost immediately insures its dissimination to and dissipation in every corner of the known world. Without tin, our present-day civilization would almost come to a standstill, and certainly the exploration of the yet unknown parts of the planet would be seriously delayed. The metal is almost as resistant as gold to the action of air and water, and to the attacks of those acids which exist in foods of all kinds, and which in a few weeks would destroy iron, and convert copper, lead or zinc into poisons, and kindly nature has segregated it in the crust of the earth in places where it may be collected at moderate cost, and utilized in activities that have become quite of the nature of indispensables to the further progress of humanity.

ZINC

This metal, which a thousand years ago was a puzzle to the metallurgists, and a nuisance to the lead miner, has become, during the last quarter of a century, one of the most useful and necessary products of the mine. The demand has increased so enormously that producers have at times had the greatest difficulty in meeting it. We have no reliable statistics of the world's output previous to 1883, when it amounted to 310,000 tons. Its principal use up to that date was for the production of brass, an indispensable alloy in the manufacture of bearings and fittings for all kinds of machinery. Previous to the present mechanical age its only use was in ornamentation. Now many other employments have been found for the metal. In the condition of an oxide it is consumed very extensively by the paint manufacturers. In the form of an electrically deposited coating on sheet iron it is in great demand by the building trade for cornice work, etc., under the name of galvanized iron, and is exported in enormous quantities to all new parts of the world for use as roofing and siding in those temporary structures reared for protection against the weather in lands where lumber is not available at reasonable cost. With the development of the electrical industries it has become a necessity in many forms of batteries, and during the last dozen years or so hundreds of tons have been consumed annually in the recovery of gold from certain of its ores by means of what is known as the cyanide process. These new uses, as well as the steady increase in the demand for brass in the ever-growing machinery trade, have caused its production to grow with such rapidity that in 1906 the crop amounted to 774,525 tons, a gain of 250 per cent. in twenty-four years. Zinc is not reckoned as one of the heavy metals, nor yet is it a light one, its specific gravity being a little less than that of iron. Yet if the product of last year was melted and cast into a pyramid with a base of an acre, the apex would stand at an altitude of about 250 feet. This is a fairly good record for a metal that in 1850 was practically unused except in the form of brass. By itself, it is a beautiful substance, almost as soft as lead, very malleable, and with a rich blue-white luster that is the delight of the artist.

History seems to indicate very clearly that nations who have possessed and developed notable deposits of the metals, have invariably taken a prominent position among their contemporaries, and have reached a higher physical and intellectual plane than those dependent alone upon agriculture or on commerce. Food crops quickly disappear. Fabric crops are worn out in a year or two. Fuel crops burn up about as quickly as they come into the market. There must be an annual harvest of these or trouble ensues. Commerce is the science of the distribution of crops, and is dependent on them for its existence. The various metal crops, however, are of the nature of permanencies. They go into *use* and not into *consumption,* and a very considerable part of each year's addition to the world's stock become articles or structures that are capable of earning interest for their owners. Probably in this lies the explanation of the prosperity that invariably results from an active metallic production. These substances can not be eaten up like wheat, they can not be worn out like cotton or wool, they can not be burned up like coal or lumber or tobacco. They remain and accumulate, are perhaps remelted and used yet another time, and even such parts as are apparently lost in the chemical arts, or in plating or ornamentation, are very extensively recovered from time to time. As a nation, we are producing about 35 per cent. of the world's crop of aluminum, 58 per cent. of that of copper, 23 per cent. of the gold, 33 per cent. of the lead, 43 per cent. of the iron, 26 per cent. of the mercury, 30 per cent. of the silver, and 29 per cent. of the zinc.[1] This is a remarkable record for a community that has existed for less than a hundred and fifty years, and it means that not only are we in possession of a part of the globe that has great mineral resources, but that our form of government and the nature of our laws are such as to foster and encourage that individualism that alone permits a people to develop the best that is in them. The metal era has but just begun. The earth beneath us is a storehouse abundantly full of them. Heretofore man has been content to utilize only those things that were on the surface of the planet. We have now begun to call upon the earth for its very heart blood. Heretofore the mason and the woodworker have been almost the sole executors of the will of the architect and the artist, but now the founder and the smith are becoming his main interpreters. Substances that can be liquefied and molded, rolled and hammered and drawn into form, are taking the place of those that with painful and long effort must be chiseled and sawn. Materials that seem to be capable of taking on life, that can be made to pulsate and vibrate, that will transport energy and light and sound and other forms of force, are being substituted for inert stone and brick and mortar, wherever strenuous life exists or is to be protected. In its future evolution

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[1] Statistics of the year 1906.

mankind is bound to reflect this great change in the nature of the materials upon which it impresses its ideals and will.

On the following sheet is given the statistics of the crop of the principal commercial metals for the year 1906.

THE METAL CROP OF THE WORLD DURING 1906

	Tons	Value
Aluminum	20,157	$15,319,320
Copper	786,794	309,996,839
Gold	675	406,931,323
Iron	64,983,481	2,323,799,280
Lead	1,061,533	120,483,995
Mercury	3,964	4,233,552
Nickel	18,983	16,879,684
Platinum	5.5	3,527,481
Silver	6,365	123,822,928
Tin	108,738	86,577,768
Zinc	774,525	69,428,421
Total	67,765,220.5	$3,481,000,591

SCIENCE AND MORALITY

By Professor ALBERT P. MATHEWS
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ONE of the most striking phenomena of the nineteenth century was the great rise of science and the loosening of religious ties coincident with a marked improvement in general morality. As it has for centuries been generally taught that morals depend upon religion, this phenomenon has to many appeared inexplicable. Indeed, some have closed their eyes to the great change for the better that has taken place,[1] so convinced are they that an improvement of morals is impossible except through religion. To them the basis of morality has seemed to be slipping away with their religious tenets.

The decadence of theology accompanying the rise of science is no mere coincidence. The general enlightenment of the age, which has been brought about by the scientific method, has undermined the Christian theology and indeed all theology in two ways: it has, on the one hand, seriously impaired the authority of the Bible as an errorless book; and, on the other hand, in a far more important way it has revolutionized the world by exalting reason rather than faith. What may be called the scientific habit of mind is incompatible with the blind acceptance of statements unsupported by evidence. Science has been justified, moreover, by the enormous contributions it has made to human happiness in the last half century. The question is, having thus undermined religious beliefs, what has science to offer in the place of religion as basis of morals? Can it take the place of religion as an aid to morals?

The discovery of the fundamental causes of moral conduct is of the first importance if we are to answer these questions and hasten the process of improvement. For it has been generally felt that our progress in national and individual morality is not so rapid as it ought to be. A method of hastening the process is sought and many suggestions have been made, the most frequent being that of teaching morals in the schools. It is obvious that before proceeding intelligently we must understand what the causes of morality are. If morals depend upon religion it would appear sensible to give religious instruction in the schools; if, however, the deep springs of good

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[1] By many people the awakening of public consciousness of the immorality of certain acts is misinterpreted as an increase in immorality, instead of the distinct improvement in morals which it actually represents.

conduct have some other source than theology or religion, then religious instruction would not be the remedy sought. Indeed, it is possible that those springs of virtue may be choked and their flow retarded by theological tenets, and the remedy proposed would not only not be beneficial but actually detrimental.

To clear the ground for a discussion of the causes of morality it is first necessary to agree on what moral conduct is. If virtue no longer consists in obeying a set of arbitrary statutes given to man by an omniscient being, what criterion shall be used in judging conduct? What makes lying, murder, adultery, covetousness, immoral, since that they are immoral we all feel instinctively? How can we tell good from bad conduct? The answer is obvious from the results which follow such conduct. All immoral acts result in communal unhappiness; all moral acts in communal happiness. The ten commandments really constitute the "common law" of morality; for, although they have been given the form of mandatory statutes, they actually represent those fundamental principles of conduct which humanity has found by experience to be necessary to human happiness. Humanity should, and does, modify and add to these basic principles as long experience shows to be desirable. We can use this criterion for distinguishing good from bad conduct and say that all acts which cause general unhappiness, or permanently diminish human happiness, are immoral; and all acts which increase it are moral. This criterion enables us to understand why different standards of morality exist among different peoples, since the immorality of any act is not generally acknowledged until the misery which comes from it is generally perceived.

Since moral conduct conduces to general comfort and immoral conduct to discomfort, one factor in the improvement of morals is obvious, for that the general happiness is influenced by the acts of individuals is perceived by all. Humanity has been driven by its own unhappiness to adopt a code of actions which produces a minimum of unhappiness. In other words, it has been driven away from immoral and toward moral conduct. This, however, is not the whole, and possibly not the most important, cause of individual morality. Such an altruistic basis of morality would probably not be a sufficiently powerful incentive to good conduct in each of us, were it not reinforced by another factor. The selfishness of the majority of men is so great that the unhappiness of others, produced by their acts, would have little effect in modifying their conduct, provided their own happiness was secured, were it not for that other factor.

There is in each one of us a fundamental instinct which actually makes the happiness of others the most powerful of all incentives to morality. Man is endowed by nature with a feeling of love for his fellow men, which makes it impossible for him to be happy and at the same time to conduct himself in an immoral manner. This instinct is the most effective incentive to civilization. It underlies all our material and moral progress; it is the source of most that is good; it is the whip driving us onward and the reward enticing us along the straight and narrow path. It is human affection, the social instinct. It is a feeling, to be sure, differently developed in different races, tribes and individuals, but it is present to some extent in all. It is a feeling which develops as one grows, extending outward from oneself. It is at first for parents, brothers and sisters, then for wife and family; for blood relatives; for tribe or nation; and finally for the race. It is the feeling of kinship. It is one of the strongest basal instincts of humanity.

The real origin of morality in the past has been this basal instinct; and it must continue to be an effective cause of morality in the future. For the love of offspring of which this instinct is part is one of the most fundamental in animals. Religious beliefs may develop or thwart this instinct, but they are powerless either to suppress it entirely or to take its place. If we should take away all religious belief, the belief in a personal God, in a future life, in rewards and punishment in such a life, we should not disturb this fundamental basis of moral conduct in the least degree. The instinct of human affection would still exist as a powerful aid to morals, one which has always existed, which always will exist and which is without any essential connection with any religious belief whatever.

Religion and science have a certain relationship to this fundamental instinct. Religion in certain ways, but unfortunately not in all, has acted as a stimulus to this instinct in each individual, and it has presented a moral code enforced by a system of rewards and punishments. The actual effect of the Christian religion on morals has been both good and bad. The rapid development of this religion at the outset was very largely owing to the fact that it appealed to and stimulated this fundamental instinct. The teachings of Jesus appear for the most part to have been directed chiefly to this end. "This is my commandment, that ye love one another." His whole life was a teaching by precept and example of the blessings of human affection. It is this element which has made the religion live; which is accountable for what good it has done in the world; which makes it unique among religions. The appeal of the religion was primarily to the feelings, but it was just as effective an appeal to the reason, if only one perceived that the real basis of all good conduct was affection.

If the early Christians had contented themselves with following Jesus's teachings in this particular, their religion must always have been a power for good in the world. But it happened that metaphysical speculation gradually wrapt around, concealed and weakened the force of those teachings. It was taught that Jesus was the son of God himself, miraculously conceived; the doctrine of the Trinity was invented and more stress came to be laid on the value of believing these doctrines than in doing the things Jesus declared to be good. The doctrine of salvation by faith became dominant and with this became associated many other conceptions, the general effect of which was to paralyze the growth of the germ of good contained in the religion. These conceptions divided man from man, race from race; they taught men to value their own salvation more than the happiness of others, and their general effect was selfish and opposed to the feeling of human brotherhood, which Jesus sought in every way to arouse, and which is the basis of morality. So completely did they modify that religion that they made of it for centuries a blight instead of a blessing, detrimental alike to moral, physical and intellectual progress. On the whole, therefore, it must be admitted that the good produced by the Christian religion has not been unmixed with evil.

Since the Christian religion was built on the same foundation as morality, not morals on that religion, and since the effect of the religion was both good and bad we can understand how it happens that the decadence of theology does not involve the decadence of morality, but may coincide with its improvement.

Morals, however, have not only not declined; they have actually improved, owing to a change in that instinct on which morality rests. The past century has seen a tremendous growth in the feelings of human brotherhood; the social instinct has been wonderfully stimulated. This is the most glorious achievement of science.

Science besides its material conquests of nature has developed human pity and compassion. It is the greatest preacher of the brotherhood of man since Jesus. Science, as a matter of fact, is developing in us just those feelings Jesus himself sought to arouse. By teaching man the causes of his own conduct, he is filled with charity and pity; by annihilating distance and time, it has broken down artificial barriers between groups of individuals; and, by the solution of the transportation problem, it has brought distant nations close together. It has shown the human race to be actually one great family, of which the misery of any part necessarily affects the happiness of the whole. The evolutionary hypothesis, the germ theory of disease, the telegraph, the telephone, the locomotive, the printing press, the daily paper, wireless telegraphy, these are the great moral apostles of the age, for they knit men together, conquer prejudice and extend our sympathies. Every discovery in science is a step forward in morality. Science is, indeed, in this way one of the greatest, if not the greatest, moral influence the world has beheld.

But science has done still more for morality than to stimulate human affection. In another and not less glorious way it has exerted a profound influence for good. It has taught the golden value of truth and candor. Beliefs, dogmas, have no place in science. More than any religion science has inculcated the love of truth for its own sake. Truth, modesty, candor! That is its creed, so far as it has any. So rare; so simple; so powerful for good! Science has patiently taught, at first to a few and now to the multitude, that the understanding of the causes of things can only come through patient and unprejudiced study. A mighty force for good has come into the world unknown to it in all its past history.

Perceiving that virtue springs from affection, it becomes possible intelligently to attack the problem of moral instruction in the schools. It would be a mistake to return to religious instruction as a basis of morality, for, as we have seen, morals do not really depend on religion and there are many tenets of the present faith which are, on the whole, distinctly detrimental or, at least, not an aid to morality. Duty, or responsibility to others, should be the key word of education. While all knowledge is a moral force, knowledge being in its nature essentially moral since it increases happiness, and while any real education is in itself a powerful aid to morality, it would be well indeed if the ideals of science could become the ideals of every one; if the love of truth and candor could permeate every individual; if the interdependence of mankind could be so clearly perceived by all that obscure crimes against the community could be recognized and detested. Above all, the whole plan of education, if it is to be efficient morally, while it stimulates the feelings of sympathy, compassion, duty and affection, must inculcate habits of logical thought, the conception of physical cause and effect, and a knowledge of the work-a-day world. For all morality has in it these three components, reason, knowledge and affection; and affection alone is instinctive and blind.

We need not worry, therefore, over the decadence of religious beliefs. All that is erroneous in such beliefs it is obviously immoral to uphold and should be got rid of as soon as possible. Unproved hypotheses, such, for example, as that of a continued, conscious existence after death, should not be taught as facts. For that man who builds his moral edifice upon such unproved beliefs is assuredly building on a doubtful foundation. What is good and worth saving in religion will be found to be working in the future side by side with science in increasing in each individual that human affection which makes man better, will he nil he, and is the really valuable thing in the characters of all of us.

Moral conduct, then, is conduct which increases human happiness. A man must be moral if he would be happy, since he has in him a fundamental instinct, the social instinct, which causes him to love his children and his fellow men, and which will not permit him to make them unhappy without making himself unhappy also. This feeling of human affection is the real basis of morals. It does not depend on religious beliefs; it will persist even though all religious belief perishes. It has been greatly stimulated by science and it is on account of the development of science that the world has grown better, while its religious beliefs have weakened. And, furthermore, anything which hinders or opposes the development in each individual and each nation of this feeling is seen to be necessarily immoral. From this point of view all obstacles to free trade, free intercourse and friendly relations between nations and individuals may be shown to have an importance in general morality.

STEPS IN THE EVOLUTION OF RELIGION

By Professor FRANK SARGENT HOFFMAN
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THE most remarkable thing yet discovered about this planet is the fact that human beings exist upon it in large numbers, scattered almost everywhere over its surface, that pay homage to superterrestrial powers. But this fact, remarkable as it is, is only a portion of the truth. For the most searching and unprejudiced investigation has failed to reveal any time in human history when it was otherwise. However ignorant and forlorn man may have been in the past, we have no evidence that he has ever been so low down in the scale of being that he did not look upward with some degree of reverence and awe to higher powers.

Not many years ago this fact of the universal prevalence of religion among men was seriously called in question by no less weighty writers than Sir John Lubbock and Herbert Spencer. They quoted at length from the reports of certain travelers and missionaries among the Eskimos of North Greenland, the Hottentots of South Africa and the Indians of Lower California in support of their position; and they stoutly contended that in these documents we have proof positive that there are communities now in existence that have no religion at all. This challenge led to a careful and thorough study of the status of these tribes by competent anthropologists, and in every case an extensive mythology was discovered among them, together with elaborate religious rites. A false idea of the meaning and scope of religion, a short stay in the country, or a lack of knowledge of the native language, had been the cause of the mistaken judgment. Probably no scholar of repute to-day would hesitate to accept the statement of Professor Brinton in his recent work on "The Religions of Primitive Peoples" that:

> There has not been a single tribe, no matter how rude, known in history or visited by travelers, which has been shown to be destitute of religion under some form.

The reason for this historical fact is a psychological one, and has never been more clearly or forcibly expressed than by Dr. Edward Caird. He asserts:

> Man, by the very constitution of his mind, has three ways of thinking open to him: he can look outwards upon the world around him; he can look inwards upon the self within him; and he can look upwards to the God above him.

And he very appropriately adds, "none of these possibilities can remain utterly unrealized."

For the fact is that man is a self-conscious being. And inasmuch as he is endowed with some degree of reason and will, he can not stand still and passively gaze at the objects about him as though he were a mere brute. He must at least exert himself enough to form some kind of a conception of the powers around and above him, and put forth some degree of energy to place himself in harmonious relations with them. But it should not at all surprise us if, at the outset of his career as a religious being, he shows the same confusion of ideas about the objects he worships, as he does about all the other matters that come within the sphere of his experience. On the contrary, we should naturally expect to find him growing and developing in his religious ideas as he grows and develops in all others.

As a matter of fact, this is actually the case, and it will be our present purpose to trace out in a general way some of the principal steps that he has taken as he has advanced from lower to higher conceptions on this subject in the course of history.

It is now generally agreed by careful students of anthropology that the most primitive form of all religion is best characterized by the word spiritism. This is the naïve and unreflective belief that most objects in this world, especially those that are capable of motion, contain an unseen being which, for the lack of a better term, we will call a demon, or spirit; that these spirits have superhuman powers and can affect for good or ill everything that concerns the ongoings of nature and the lives and happiness of man. In this stage of development human beings attribute all their pleasant experiences to friendly demons, and all their disagreeable ones to just the opposite source. Hence they make use of every means in their power to win the favor of the good spirits, and ward off the envy and wrath of the bad.

The reason for this state of things it is not hard to find. For when the primitive man first begins to give form to his religion, he is himself the only being that he knows anything about that possesses the power of spontaneous action. He can not help attributing the same power to all the objects with which he in any way comes in contact. He acts just as every little child acts in a similar condition. Any object that constantly gives a baby pleasure it pats and caresses with affection. The one from which it gets a hard pinch or knock it wants to pound and kick with all its power. It spontaneously assigns to the object the same sensations and feelings and will as it is itself conscious of. Its experience is so limited and crude that it does not know enough to do otherwise. So it is with primitive man. To him every other is another, and he attributes to that other all of his own powers. In his opinion the world about and above him is made up of a vague, indefinite host of superhuman demons or spirits, and the form of his religion is determined by that fact.

Another thing that confirmed the primitive man in the belief that he was surrounded by a world of supersensuous beings was his experience in dreams: when he had developed far enough to remember his dreams with any vividness, he always thought of them as real experiences. The beings that visited him in his sleep were as genuine realities and as truly to be dealt with as any that he came in contact with when awake. In fact, he finds that he can often do things in dreams that he can not do when awake, and that he frequently communes with beings that he has no knowledge of when awake. The Kamchatkans and Eskimos, we are told, determine what they will do when awake to a great extent by their dreams; for they regard the knowledge obtained in this way far superior to that gained through the senses. Lucretius, however, goes too far when he asserts that "the dreams of men peopled the heaven with gods." Many of the lower animals are vivid dreamers, but they show no signs of having any religion. Still, dreams in all ages have often been regarded with superstitious reverence, and were undoubtedly an element in determining the character of the primitive religion of mankind.

It has come down to us from the Latin poet Petronius that "fear first made the gods." As a complete statement of the origin of religion, it is contrary to the history and nature of man. The primary religious influence is not fear, but confidence and awe. The spirit of many early religions was quite the opposite of fear. "Probably the first of all public rites of worship," says a high authority, "was one of joyousness, to wit, the invitation to the god to be present and to partake of the repast." Many modern students of the subject would bear witness to the presence of joy and confidence in primitive religions.

Yet it can not be denied but that fear early came to be one of their most important elements. For just as with the little child, the primitive man was often disappointed in his confidence. As his experience widened and the ills of life multiplied, he began to doubt the friendly character of the spirits. He soon came to the conviction that some only were favorable to him. The rest were to be feared. And as fear once aroused feeds upon everything within its grasp and grows with extraordinary rapidity, the uncertainty as to what the attitude of the spirits would be toward him naturally caused the primitive man to spend the most of his energy in devising ways to appease their wrath.

A slight step in advance beyond spiritism was taken when the opinion began to prevail that all objects do not contain superhuman beings, but only some of them. This stage in religion is called fetishism. The term was first applied by certain early Portuguese explorers to the objects worshipped by the savage tribes they discovered in Senegal and the region of the Congo. They found some of these peoples paying homage to such objects as a piece of wood, a feather, the fin of a fish, the claw of a bird, the hoof of a goat. Others among them regarded with reverential awe a big rock, a grove of trees, some such animal as a snail, a snake, a lizard or a crocodile. In fact, anything became an object of worship to them when they fancied that a powerful unseen being had attached himself to it.

The fact that no man ever worships a material object is well illustrated by the treatment accorded a fetish. If a fetish brings good luck, it may be sold for a high price if the owner wishes to part with it. If it brings bad luck, it is thrown away or demolished. For all virtue has gone out of it. The spirit that was in it has departed, and it has lost its power. The favorite fetish of a Papuan of New Guinea is a little wooden doll with a bright-colored rag tied around it. If a stroke of ill fortune comes to him when he has this in his belt, he will take it out and stamp on it, or tear it in pieces with his teeth, and cast it from him as utterly of no value.

As we go about over the surface of the earth, we find that different tribes have selected different objects for their fetishes, according as the objects have impressed themselves upon them as possessing superhuman powers. Among the Maoris of New Zealand spiders were paid divine honors; for it was in their gossamer threads that they fancied the souls of the departed ascended heavenwards.

Some of the Indian tribes of the northwest regarded the raven, or the thunder-bird, as they called it, as especially sacred; and according to Capt. Cook, the Sandwich Islanders also did so. The peacock, the swan, the rooster, the eagle and the dove, have been the favorite fetishes of other tribes. In Australia and Polynesia the lizard was greatly revered. The Chaldeans paid the fish divine honors. In Egypt the ox was especially sacred, and so it is in parts of India. In certain of the Fiji Islands the shark is worshipped, just as the alligator is in the Philippines. The Samoyeds in Siberia make a fetish of the whale and the polar bear.

But the most widely worshipped of all animals is the serpent. Mr. Ferguson, in his work on "Tree and Serpent Worship," finds that the serpent was accorded divine honors by nearly all the nations of antiquity, and is now worshipped in many parts of Asia, Africa and America. Among the Lithuanians in southern Russia, says a high authority "every family entertained a real serpent as a household god." Sir John Lubbock tells us that in Liberia

> No negro would intentionally injure a serpent, and any one doing so by accident would assuredly be put to death. Some English sailors once having killed one which they found in their house, were furiously attacked by the natives who killed them all and burned the house.

Closely allied to fetishism, yet indicating some advance in the evolution of religious beliefs, is ancestor-worship. This easily arises when man has developed far enough to begin to meditate upon the phenomena of death. At the very outset it is likely that death did not arouse much more interest than it does now among brutes. Britton asserts that

> The evidence is mountain-high that in the earliest and rudest period of human history the corpse inspired so little terror that it was nearly always eaten by the surviving friends.

But even this custom was probably of a religious origin. A traveler (D'Orbigny) in Bolivia tells us of an old Indian he met there whose only regret in giving up his old religion and adopting Christianity was that his body would now be devoured by worms, instead of being eaten by his relatives.

At all events, it early became an elaborate and solemn religious rite to provide the body with carefully prepared viands for its last long journey. Any neglect on the part of the survivors would be severely punished. For the soul of the departed would continue to roam about without a home, unless it was properly attended to its final resting place. Hence it became the world-wide custom among savage tribes to place in the tomb or on the funeral pyre such articles as the weapons, the clothing and ornaments of the deceased. In many cases the wives or slaves or companion-in-arms were slain or slew themselves to accompany a chieftain to his long home. Often among the American Indians they were interred in the same mound, and many such mounds exist in different parts of the country.

When a tribe had survived so long as to have a history, and to trace its descent through the male head of the family, a decided change in their religious views usually followed. As Giddings describes it:

> While the household may continue to regard natural objects and forces and miscellaneous spirits with superstitious feelings, they entertain for the soul of the departed founder of the house the strongest feeling of veneration. They think of the ancestral spirit as their protector in the land of shades. To the ancestral spirit, therefore, they pay their principal devotions.

We find it generally true that the family tomb was near the house and not far from the entrance. The children were brought up under its shadow, and constantly addressed to it their prayers. Within the house on the family altar burned the sacred fire that went out only with the extinction of the family. Around this fire all the household dead were supposed frequently to assemble to hear their mighty deeds narrated and to be reverenced and adored.

All the ancient Semitic tribes were ancestor-worshippers, and so were the Aryans when they first appeared on the shores of the Mediterranean. The Egyptians carried the cult to a high state of perfection, and the manes-worship which long held sway among the Romans is an example of it. It is to-day the religion of the Bantu tribes of Africa, and still prevails to some extent in Japan. But it is chiefly among the Chinese that this form of religion has reached its highest form of development. All changes in the customs of the country are resisted as a reflection upon the regulations established by their ancestors, for the infraction of which they will be severely punished. The greatest sin they can commit is to allow the graves of their ancestors to be disturbed for any cause whatsoever.

As men progress in their knowledge of the things about them, they come to see the defects in the forms of religion described above, and begin to turn their attention to more exalted powers. They cease to pay exclusive homage to the spirits that reside in the objects that they themselves have handled and can make or destroy, and begin to look up in reverential awe to the beings that manifest themselves on a vaster scale, and in a more consistent and impressive manner.

Thus arose what is usually called nature-worship, the most prominent form of which is the worship of the celestial bodies. It is probable that the division of the week into seven days came about from the dedication of one day to each of the gods manifesting himself through the seven greatest luminaries.

Naturally, in all except the torrid zone, the sun-god received the greatest homage. As the source of light and warmth, as the earth's great fructifying power, as the one constant ever-recurring factor in man's daily experience, it has always awakened the most powerful religious emotions, in the minds of rude as well as semi-civilized people. Among the ancient Phœnicians the sun was the center of their cultus. It was probably the leading feature of the religion of the ancient Persians. The same was also true of the Sabeans. The worship of Apollo, so popular among the Greeks, was in all probability sun-worship. The Egyptians gave the sun a high place in their system, and the ancient Peruvians paid it their chief honors. The Celts and the Teutons, as well as the East Indians, made much of it, and so do numerous tribes in Africa to-day. It is maintained by many writers that the North American Indians were always and chiefly sun-worshippers; that the sun was actually their Manitou, or Great Spirit.

In some lands the moon was fixed upon as the chief deity. Certain Australian tribes believe to-day that all things, including man, were created by the moon.

At all periods of the world's history the stars have received special homage. Among the early natives of Greenland and Australia the Milky Way was nothing less than the pathway of souls ascending to their home in the heavens. The auroras borealis and australis were actually in their opinion the dance of the gods across the firmament.

Another form of nature worship was the adoration of the fire-god.

Among all peoples fire has been held sacred. It was thought of as the central principle of life. Among the Kafirs in South Africa every religious ceremony must be performed in front of a fire. The Indians of Guatemala regard it as their greatest and oldest deity. The fire test was practised by the Aztecs of Mexico, as well as by the Moloch worshippers of Syria. In Borneo the crackling of blazing twigs is the speech of the gods. The vestal fire of old, and the perpetual fire of the modern Christian altar are both founded upon the assumption of its sacred character.

As the experience of man widens, he discovers not only that he can destroy the tree whose spirit he worshipped, and can entrap the animals and subdue them, but also that the sun, moon and stars do not vary their action at their own option. They are obliged to move about in certain more or less prescribed courses. Even the clouds are driven to and fro by some superior power and are not free to follow their own desires. Hence he easily and naturally comes to see the truth that there must be powers above these forces that are far more worthy than they are of his homage. He rejects the notion that the forces of nature reveal the highest spirits, and he looks up to deities that can use these forces freely at their option. As distinguished from nature-worship and other lower forms of religion, this doctrine is called polytheism, although it differs from these other forms not in kind, but only in degree.

Undoubtedly, the development of this doctrine is closely related to the development of the social and governmental relations existing among the people themselves. When chiefs and kings begin to make their appearance in any community, then these greater gods begin to be recognized as over and above all lesser spirits. Oftentimes the kings and chiefs themselves are elevated to the sphere of gods, and in some cases, even while alive, receive divine honors. Rarely, however, does polytheism do away with any of the lower forms of religion. On the contrary, it usually coexists with belief in disembodied spirits, local genii of rocks and fountains and trees, household gods, and a host of other good and evil demons. The deities of this form of religion simply take their place as presiding over all inferior gods, using them as messengers or agents for the furtherance of their plans and purposes.

At first, each tribe or district is thought of as having its own particular deity. But as the tribes intermingle and learn more of one another, the tribal gods give way to national. At the outset the national gods of one country are regarded as distinct from those of another, but of equal powers. Even the ancient Hebrews considered the gods of other nations, such as those of Assyria, Phœnicia and Egypt as real divinities.

Many tribes and peoples have risen in some degree to the stage of polytheistic thought, but the nations that carried it to a higher degree of perfection than any others were the ancient Greeks and Romans. Costly temples were erected to the honor of their gods. Elaborate ritualistic services were instituted to do them reverence. A great multitude of priests and priestesses devoted their lives to finding out and enforcing their will and purpose. The character and extent of this form of religion are, however, so familiar that there is little need of further explanation of it here.

This can hardly be said of monotheism, the next step in the evolution of religion. For there has been and in some quarters still is a great divergence of opinion regarding its historic origin. For until within a few generations, it was the common belief of thinkers on the subject of religion that the knowledge of the existence of one god was a primitive revelation, made to the first representatives of the human race, and handed down by them to their posterity. Polytheism and all other forms of religion, it was maintained, are a degeneration from a once higher form. But this view has few if any advocates among recent scholars. For it is now known that the tendency to the monotheistic position exists among all people when they have advanced to a certain degree of mental culture. As Jastrow well says:

> There is a difference in the degree in which this tendency is emphasized, but whether we turn to Babylonia, Egypt, India, China or Greece, there are distinct traces towards concentrating the varied manifestations of divine powers in a single source.

This tendency is a perfectly natural one, and arises the moment man begins seriously to reflect upon the universe. He can not fail to observe the inequalities that exist among the deities, and to realize that of necessity one must be supreme to all the others. When any two peoples united as the result of war or for any other reason, the superior place would naturally be accorded to the deity of the conquering power; and as a nation grew in influence and became conscious of its strength, it would gradually change its opinions regarding the gods of the nations about it. It would either do as the Greeks did in the case of Ammon, the god of the Egyptians, recognize in him their own Zeus as appearing in another form, or come to treat other gods as inferior deities not worthy of being compared with their own god, as the Hebrew looked upon Chemosh, the supreme god of the Moabites, in comparison with Jahveh, or Jehovah, their own national deity.

It is a matter of history that monotheism did not originate in any one quarter alone, but was an idea attained independently by many people at a comparatively early stage in their development.

The chief contribution of the Hebrews to religion is not their monotheistic idea, but the emphasis they put upon the ethical character of their supreme deity. He was not mere power that goes stalking through the universe, but a being of righteousness that deals with men and nations according to their moral character. It was this view that caused the worship of Jehovah to supplant that of all the other gods among the Hebrews themselves, and to survive the crash of faiths that early befell the entire ancient world.

In this brief outline of the main steps that have been taken in the development of religion, it is not claimed that any hard and fast distinction can be made between them. Indeed, it is the opinion of competent authorities that all the different forms of religion described above coexisted among the Hindus, the Greeks, the old Norsemen, and to some extent still coexist among modern Africans, as well as the negroes and Indians of our own land. Nor is it held that any sudden or complete transition from a lower to a higher stage has actually taken place at any time in history. On the contrary, the changes have been gradual, and many evidences of the survival of the old amid the new exists in the notions and customs of even the most highly civilized and intelligent nations of our own day.

Amulets, charms, lucky stones and coins, the veneration of sacred relics, everything that goes under the name of "mascot," are all legitimately descended from fetishism; just as belief in ghosts and haunted houses, fear of the dark, and the like, come from a more primary form of religion. Current ideas concerning lucky and unlucky days and numbers, spilling salt, throwing rice at a wedding, charming away warts, are survivals of a similar sort. So, too, are the present notions of man as to sacred days and places, sacred utensils, holy water. And we should not hesitate to class in the list of primitive and outgrown religious ideas the worship of saints, and the common belief that a person acquires peculiar supernatural authority in religious matters by the laying on of hands, or by any other form of ordination. For they are notions on a par with the old Greek tradition that one gets a supernatural inspiration by the very act of paying a visit to the fountain of Parnassus, or taking a draft at the Pierian spring. But the most striking of all is the present popular belief that between man and the Supreme Being there exists an ascending gradation of angels and archangels on the one hand, and evil spirits on the other, reaching up to a supreme evil demon, who, under the title of Devil or Satan, is supposed to be the author of the sin and misery of mankind.

In the light of this view of the evolution of religion, we can see how irrational it is to divide religions into true and false, instead of classifying them as primitive and developed. It was maintained by Empedocles among the ancient Greeks that all religions are false because they are the product of a diseased mind, and Feuerbach in the last century strongly advocated the same view among the Germans.

While few, if any, maintain that opinion at present, there are many who hold that all religions are false except one, and that the one they themselves have come to adopt. The Jew does this who asserts that God by a perpetual covenant, recorded in the Old Testament, has made his own race the sole repository of his will. The Islamite does this who regards the Koran alone as the sole guide to truth and life. And the Christian who sees in the New Testament the only source of religious faith and practise belongs to the same class. No writer has given us a more vivid picture of the erroneous way of regarding the religions of the World than Milton in his "Paradise Lost." That all religions except the Christian are pure inventions of the Devil to ensnare the unwary is his fundamental thought.

This position has been the source of untold mischief and suffering in the past, and immensely impedes the progress of mankind at present. It is contrary to actual fact, and is based upon the false assumption that man possesses the ability to acquire absolute certainty in religious matters, a thing which is denied to him in every other sphere.

The truth is that man's religion develops as he himself develops. The steps in the evolution of religion are the steps in his own mental advancement. There is never a time after he comes into conscious possession of his powers as a person when he is without religion, and there is no possibility of his outgrowing religion. He does not get his religion out of any book, but primarily out of the experiences of his own mind and heart. The experiences of others are a help to him only as he reproduces them in his own. The more sensual he is, the more sensual will be his religion, and the more rational and pure his life is, the more refined and spiritual will his religion become. In other words, the more of a man he is himself, the loftier will his conception be of the Maker and Sustainer of the universe.

THE AMERICAN PUBLIC SCHOOL

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HORACE MANN, speaking in 1841, said: "A practical unbelief in the power of education—the power of physical, intellectual and moral training—exists among us, as a people." Two generations later are we still, as a people, unbelievers? We extol with fervor, with acclamation, with volubility, free schools; we pay our taxes not too unwillingly, spend an occasional session in our children's schools, help John and Mary, spasmodically and ineffectively, with their harder lessons, send them at some sacrifice to a high school or perhaps to college, and then thank God for the priceless blessing of a liberal education!

Having thus, with characteristic amiability and liberality done his duty according to the custom of his neighbors, the average American proceeds to exalt the "self-made" man, to deride the college and even the high school graduate, and to wonder why, with free schools and compulsory schooling, crime, folly and corruption flourish so amazingly. As in 1841, there is a "practical unbelief," not in education itself, but in the thing called education which most schools and colleges give.

We Americans pride ourselves upon being a practical people, yet fail to treat education as a practical question. Therefore, as a rule, our public schools are neither practically governed nor fitted in a practical way for the ends which they should serve. Blinded by time-honored fictions, we ignore the plainest facts. Paying vast taxes for the support of schools, we act as though the spending of that money would be guided by Divine inspiration. Making this upon education one of our largest outlays, we are content that such an enormous expenditure should be in the hands of changing and irresponsible boards, to most of whom the problems of education are as remote as the wisdom of Confucius. Setting in motion the machinery upon which we depend for the quality of future citizenship and therefore for the very existence of the republic, we are, as a rule, quite heedless whether that machinery turns out youth well fitted or totally unfit for the duties of men and women. The public schools are a business investment which stern necessity taught the founders of the nation the wisdom of making; yet the hardest thing to impress upon this nation of business men is that simple and fundamental fact.

Without public education genuine democracy is impossible; therefore the democratic state must make provision for free common schools. From every point of view, however, especially from that of the pupil's own good, those common schools should be regarded as investments from which the state, if it would prosper, must get the best possible returns. All measures in education, be they of the kindergarten or of the college, should be judged mainly from the standpoint of an enlightened political economy, from the standpoint, that is, of securing the greatest good for the greatest number by the least expenditure of social force.

Quite as much for our sakes as for theirs we require all children of certain ages to attend school and, directly or indirectly, tax ourselves to pay for this free teaching. But in paying taxes and in voting for a school board—supposing even that we do the first cheerfully and the second with some shadow of knowledge of the candidates—we are fulfilling but a small part of our duty to youth and to ourselves. There are at least two other obligations. The first of these—since we compel the child to go—is to make sure that his schooling is the best obtainable; the second—since we contribute so much to the cause of education—is to make certain that we secure the equivalent of this money in the quality of citizenship which the schools produce. If we acknowledge the wisdom of educating every child; if, not simply recognizing it, we actually compel it and set up a system against which private enterprise is powerless to compete, it would seem but plain duty to make this compulsory education humanly perfect. Even failing, however, to recognize this moral obligation, it still remains extraordinary that a nation so shrewd as ours, lavishing millions upon free education, should not look more closely to it that industrial capacity, mental and physical strength, and effective citizenship result.

Being, so to speak, a protected monopoly, the public school, to justify its favored position, should do as much for every child as any other means of education, were it free to maintain itself, could accomplish. As long as the claim can anywhere truthfully be made that parents must send their children to private schools in order to their best education, just so long the public schools are falling short of their full and essential service, a service that involves the giving, not of mere instruction, but of real education. To prepare youth for civic duty and for industrial, business or professional life, the free schools must furnish those means of intercourse, those fundamentals of a civilized society, which the casting of a ballot and the pursuit of a business or a trade demand; but, in addition and far more importantly, they must lay such foundations that every youth, broadly speaking, may become the best workman, the most successful man of affairs, the completest citizen that it is possible for him to be.

A man's real success in life is determined by two things: the degree of development of his faculties and his conduct as a member of society. It follows, therefore, that the two main ends to be sought by a public school are to give the boy command over himself and to teach him how to be a useful citizen. That is to say, public education exists in order to develop human power, and the kinds to be developed by a school are two: social power and personal power. The school must do the most it can to perfect every one of its pupils in the ability to play the largest part possible to him in the life of the community; it must help him, also, to make the most of himself. Of course these two ends of education intertwine; one can not make a boy a good citizen without making him, at the same time, a better man; neither can one make him a good man without producing, concurrently, a better citizen. To make a boy perform his due part in society he must be taught the arts of social life: how to read, write and cipher, how to comport himself, how to maintain pleasant relations with his kind. Moreover, this body of upgrowing youths must be trained and accustomed to act together, to feel their interdependence, to see the interrelations of the vast social structure perfection in which has made modern civilization possible. But, more than this, the school must, so far as it can, train, foster and direct the physical and moral forces of every individual child towards his highest individual development.

The boys who enter a counting-house or factory, the girls who take service in a shop or kitchen, the citizens who, in uncounted ways, maintain their communities and support the sovereign state, must, as a rule, know how to read, write and cipher. To do these things well counts greatly in their favor. That so many do not do them well is a serious charge against the public school. These, however, are not the fundamental qualities which employers seek and which communities require. They demand health, character, honesty, truth-telling, clean living; they demand willingness to work, readiness to comprehend, quickness of adaptation, fertility of resource, vision; they demand alertness, vigor, self-command, dexterity and muscular control. These things which result, not from set lessons, but from self-discipline, self-reliance, self-knowledge, determine the success of a boy or girl in life, and these qualities the public school must seek to develop through every means and every force at its command.

Looked at from any point of view, economic or moral, physical health is the fundamental material good of mankind. Yet what contribution does the ordinary public school make towards hygiene? As a rule it crowds fifty or sixty children into a room that, under the most favorable conditions, has fresh air enough for only thirty. It places no bar against the unwashed child, gives him no incentive or opportunity to be clean; therefore most schools contain enough of these effectually to poison the atmosphere for those who are kept decent. All these children, breathing an insufficient quantity of more or less polluted air, are in many instances cramped into penitential desks, ten minutes' stay in which provokes intolerable restlessness, and are told by a much overworked teacher, also ill-supplied with a like bad quality of air, to keep still and to do a uniform task, a task which is too easy for some, too hard for others, and mainly distasteful to all. The teacher does her best; the pupils do better than one would suppose; both are victims of ill-planned conditions. Nothing superior to rigid discipline and unvaried tasks can be thought of when sixty little individualities, bursting with life and spirits, must be dampened into order and dragged forward somehow into that formidable next grade by an overwrought teacher whose work is judged solely by its outward results.

The inevitable outcome of such conditions, especially with growing girls and the teacher herself, is headache, nervousness, ill-temper—all the present and future ills which lurk in this Pandora's box of bad hygiene and overcrowding. Moreover, to serve as an antidote, we find in most cases nothing but some listless calisthenics, monotonous marching, and aimless romping in a bricked back-yard. So much do most schools contribute towards that foundation of a useful life, good health. Alertness, vigor, dexterity, self-command, individuality, can hardly develop out of such anti-natural conditions as these. The boy may be vigorous, alert and dexterous; but it will be in spite of the school, it will be because his life outside the schoolroom, that life which he loves, is full, as the school life is devoid, of the means to encourage those admirable and necessary qualities.

And those other virtues which the employer of young men is always seeking and so seldom finds, for which municipal life is crying out, without which the nation will perish—does one get them, as a rule, because of or in spite of the public school training? Does the setting of uniform tasks, with penalties for their neglect, either uniform or gauged by the passing temper of the teacher, develop an eagerness to work and a delight in labor? Do wholesale lessons explained by wholesale to sixty children, each one of whom has a different mind-content, a different means of apprehension, each of whom needs, therefore, special leading over every new difficulty—do these tend to promote readiness, quickness and alertness? Nothing, on the contrary, could be better calculated to dry up that intense eagerness to know, that grasping after new ideas, which most children come to school with and which, alas! so many go away without. Do desiccated text-books, rote work, graded lessons, the whole abominable system of yearly promotion, result in that quickness of adaptation, that fertility of resource, which are the very soul of civilization? Is honesty encouraged by the usual school discipline and methods? Does truth-telling always plainly get its reward? Is purity fostered by the promiscuous herding of hundreds of children, old and young, corrupt and innocent, in the same building, under teachers whose time must be given to mint, anise and cummin rather than to these weightier matters of the Eternal Law? Says M. de Coubertin, "Not ignorance and sloth of mind threaten our younger generation so much as moral inertia and atrophy of the will. The supreme problem is to cure these." This moral inertia can be overcome, this will of the child can be developed and trained only by treating each pupil as a special problem to be worked out with knowledge, with sympathy, with tact, with enthusiasm, by every teacher under whose control the child is brought.

The bottom fallacy of much of the acknowledged inefficiency of public education is that equality implies uniformity. We are to give all youth an equal chance; therefore let us put it through one common course of study, therefore let us give it a discipline of the barracks. But this is not to secure to children an equal opportunity at all. Whose omniscience devised this uniform course which is so to act upon the antipodal natures of John and of Patrick, of Marie and of Tessa as to give them an equal chance to develop into their very best? Who found this universal solvent of all the oddities, stupidities and personalities of a townful of child nature? A uniform course is the very embodiment of inequality, making the weak weaker, the dull duller, the cross-grained more out of touch with the rest of mankind. Such a course may suit three children out of every twenty; but the remaining seventeen are mainly stupefied by it, learning only to associate what is most disagreeable, what is most useless, what is most quickly to be forgotten with those school years during which it was vainly attempted to fit their tender and growing individualities to an arbitrary mould. The only way in which to give every child an equal chance with every other is to provide for each the atmosphere and incentives suited to his particular needs and nature. Then that nature will respond and grow, revealing powers and aptitudes inconceivable under the blight of uniformity. There is no such thing as an "average child." He is a fiction as absurd as the passionless man of the old political economy. As well might one talk of an average vegetable and subject all plants to an unchanging regimen.

The fundamental principle of the "new education" which is as old as India and Greece—is to develop and strengthen individuality. All men are born free: you shall not make them slaves to a fictitious average. All men are born equal before the law: you shall not make them unequal before the law by forcing upon them a common training which gives those few whom the course happens to fit an enormous advantage, leaving the rest substantially untouched by the real forces of education. So much of the military, disciplinary side of the school as promotes solidarity, makes children feel themselves to be social units, favors the impulse to activity arising from mere mass, is vital to the state. The marching together, singing together, playing together (provided the play be judiciously organized) is a splendid stimulus to social and civic life, impossible to be done away with. Along with this, however, and all the more strongly because of this, the individuality of the child must be nourished, promoted and developed by every rational means. Within the range of his powers all health, virtue and capacity are within him as the germ is within the seed. The teacher's business is to stimulate, to encourage and also to prune, these elemental forces. This can not be done by instruction given by wholesale, but only through genuine education acting directly upon the individual child.

Shall teachers, then, be converted into nursery governesses, one to each pupil? That extreme would be worse than the other. Under a right plan of public education, however, no teacher would have charge of more than twenty pupils; and no teacher would have charge of any at all unless, by temperament, by understanding of child nature, by a thorough professional training, he or she were fitted to make out of every one of those twenty pupils the most that can be made. Such professionally trained teachers, with classes limited to a proper size, would not simply instruct, they would really educate their pupils by giving them the tools of knowledge, not as dead processes, but as living means to illimitable ends. Out of the common, elementary studies, with no loss but with great gain in form, they would develop the content of literature, of power of expression, of sober reasoning, of world interest, of nature interest, of social and civic responsibility; and upon these fundamental studies they would lay the solid foundations of self-reliance, self-knowledge, self-respect. They would do this, moreover, not through dependence upon text-books, routine, and uniform lessons; nor, on the other hand, would they do it by excursions into psychological subtleties or by pandering to their pupils' and their own self-consciousness. They would do it as every intelligent, human man or woman who has the "faculty" of teaching and who has been taught to teach, knows how to appeal to the differing nature of each child, making him see the common fact from his special point of view and assimilate it to his personality, thereby building up by sure degrees his individual character.

Such teaching—and this is no vision; it has been demonstrated again and again—would make most children eager to go to school, impatient to learn, greedy of every new chance of mental and moral growth. Out of such an atmosphere would come a race of artisans and business men—better still, of citizens—such as the world has not yet seen. It would be a really efficient race of *working men*, neither wasting time and materials, nor shirking what they have to do; for they would have been taught how to work, how to concentrate themselves upon a task, how to get pleasure from the mere act of doing thoroughly and well. It would be a race of studious and inventive workmen, of progressive business men and of enlightened citizens; for they would have tasted the delight which comes with the use of the acquisitive faculties, with nimbleness of wit, ingenuity of thought and adaptation of means to ends. It would be a race of self-reliant and self-respecting artisans, traders and individuals; for they would have been shown the enormous significance of the *ego,* who makes his own career and who, if he will, can make that career of tremendous importance to his day and generation.

Such a diminution in the size of classes, such an insistence upon supreme fitness in the teacher, will add incalculably to the cost of public education, through doubling the number of teachers and through doubling or trebling their pay: for present salaries will not warrant such a professional training as the new education demands. From the industrial standpoint alone, however, this added expenditure would pay vast dividends. There is frightful waste of power in the burning of coal to run a locomotive; but it is as nothing to the waste in the industrial world in the attempted utilization of human power. Ill-health, low physical force, untimely death, intemperance, vice, crime, manual inefficiency, stupidity, lack of interest, shirking—all these and many other human failings continually clog and stop the industrial machine, so that it would scarcely be an exaggeration to place the effective power of the millions engaged in gainful occupations at one tenth of what it should be. If by proper schooling this efficiency could be doubled—and it is reasonable to say that it could be much more than doubled—how infinitely would such a gain outweigh the added cost of a rational public education.

No startling changes are necessary in the free school system. Its general plan is admirably suited to American conditions. It needs but to be altered in this detail and in that, in the expansion of this principle and in the suppression of that practise. We must, however, do away with the curse of uniformity, allowing, instead, full play to individuality; we must, furthermore, fit the means and methods of the school to the real needs of the future worker and citizen; and we must, in addition, make the profession of teaching self-respecting by releasing it from its present bondage to amateurs, to well-intentioned but inexpert school boards who are jauntily settling pedagogical problems that appall trained experts. The teachers, if they are to teach from themselves instead of from prescribed text-books, must have a larger share in the control and development of schools and must be so trained and stimulated as to be fit to assume that larger share. Not elaborate buildings, or reformed courses of study, or wiser supervision will, of themselves, make the new education succeed—it will be the teachers: and if this vast responsibility rests upon them, with them must rest also power and initiative, in them must appear professional pride far beyond what they possess to-day.

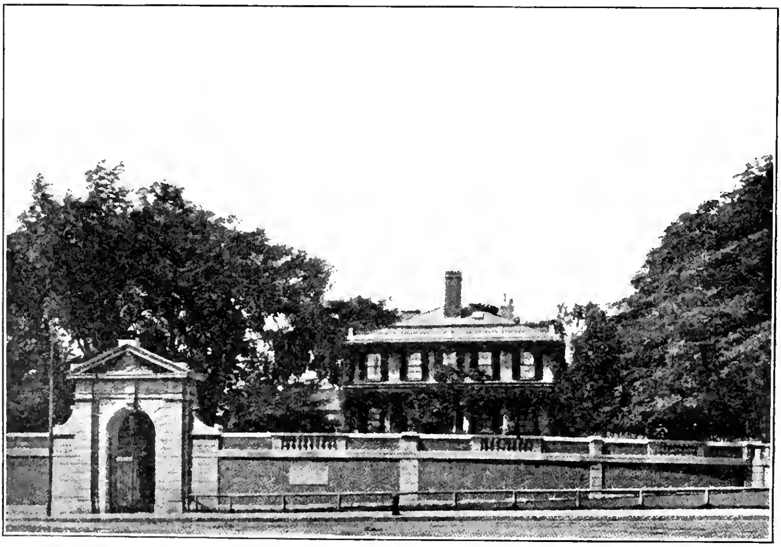
These fine, great schoolhouses, with all modern devices—provided their ventilating systems work, their floors are kept clean and their rooms are not overcrowded—are admirable; but they do not in themselves educate. The complicated apparatus, the works of art, the libraries, with which many of those schoolhouses are filled, again are admirable: but in themselves they are mere sticks and stones. The subdivision of labor among teachers, the calling in of specialists, the elaboration of methods of teaching are—sometimes—excellent; but they are but the husks of real education. Psychological laboratories, child-study, the heaping up of great masses of pedagogical data are also, when backed by real knowledge, excellent: but they are only minor helps to a real education. Pile buildings, apparatus, methods, psychological subtleties high as Pelion on Ossa and there will result no better education than was given in the ancient district school unless behind this complexity of educational machinery are real teachers knowing how to teach and with time to do true, individual teaching. The more we elaborate education, the more time we spend on pedagogical minutiæ, the more we load ourselves down with apparatus, the more plainly it appears that the sole essential for real education is the educated teacher who knows how to teach. Upon his, or her, personal fitness rests the future of the country; with him, or with her, not in systems and apparatus, lies the solution of this vexed question of the public school. The regeneration of mankind will be brought about, so far as the common school can effect it, by the direct, human influence of the individual teacher upon the individual pupil.

Such teachers, however, will not appear in numbers sufficient to make their influence felt until they are assured of decent remuneration, of tenure of office during real efficiency, of small classes, and of a professional standing regulated, as is that of physicians and lawyers, by the profession itself. And only when the great public gives that assurance, by its individual and corporate support of those who are trying to foster the new education, will it prove that it really believes now, any more than it did in 1841, in the actual "power of physical, intellectual and moral training."

THE PROGRESS OF SCIENCE

HARVARD UNIVERSITY AND THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Boston is still the chief educational center of the country. Among its institutions for higher education, Harvard is our greatest university and the Massachusetts Institute of Technology our greatest school of technology. This year Harvard is for the first time surpassed by Columbia in the number of students, and it will soon be overtaken by several of the state universities. Cornell and Michigan have more students in applied science than the Massachusetts Institute of Technology. But Harvard and the institute have been leaders in setting certain educational ideals, and each will for a long time maintain its preeminence. Harvard consists of a college with free electives for culture and professional schools based on it; whereas the institute aims to give culture with and through its professional studies. The outcome appears to be more play at Harvard and more work at the institute. It is extremely difficult to appraise the value of an educational system by its results on the students. So long as students of the upper classes with their hereditary and social advantages or students selected from all classes by their superior ability and enterprise go to college, and so long as the college is the natural gateway to certain careers, it is not possible to test the value of a college education by its objective results on the future success of the students. When, however, the graduate school of applied science endowed with the income of the McKay bequest at Harvard has been completely established, it may be possible to make an interesting comparison of its work with that of the institute.



The President's House, Harvard University.

Professor A. Lawrence Lowell,
President-elect of Harvard University.

It is a curious fact that the two institutions, after the unsuccessful attempts to form a merger two years ago, should now at the same time elect new presidents. In the men selected and even in the methods of selection, the institutions have shown their individuality. Harvard has in the most gentlemanly manner elected a member of its own set; the institute after floundering about has chosen a man from the antipodes.

Professor A. Lawrence Lowell, elected to succeed Mr. Eliot as president of Harvard University, belongs to the Harvard and New England aristocracy. The cities of Lowell and Lawrence were named from his ancestors, who for generations have maintained traditions of wealth and culture. Of this stock he is typical, even to the extent of having married his cousin and having no children. In an address made very shortly before the election of his successor, President Eliot said: "When the corporation selects some young man to take my place I hope you will all look at him with this one inquiry—is this a promising young man, is he a young man who has in him a large capacity to grow?" But the corporation chose a man completely formed by heredity and experience, eminent as an author of important books on government, trained first as a lawyer in charge of large vested interests and later as a professor, lecturing in courses attractive to college students. We may be sure that Mr. Lowell will be as exemplary as president of Harvard as in every other relation of life, and that the traditions and spirit of the university will be safe in his hands.

Professor Richard C. MacLaurin, president-elect of the Massachusetts Institute of Technology, though born in Scotland and completing his university studies in Cambridge, has spent most of his life in New Zealand, where he was professor of mathematics in Wellington. A little over a year ago, he accepted the chair of mathematical physics in Columbia University, which had been vacant since the election of Professor R. S. Woodward to the presidency of the Carnegie Institution. Professor MacLaurin has recently pub-

Professor Richard C. MacLaurin,
President-elect of the Massachusetts
Institute of Technology.

lished the first volume of an important work on mathematical optics. He has also been trained as a lawyer and has broad interests in philosophy and education.

It is a fact of some interest that Mr. Lowell is a member of the corporation of the institute and with Dr. Pritchett represented the institute in the joint committee of the corporations which recommended the merger with Harvard. The most important action of Harvard since the election of Mr. Lowell has been the calling of two heads of departments of the institute, Professor Swain and Professor Clifford, to its Graduate School of Applied Sciences.

ENGLISH VITAL STATISTICS

The recently published report of the English registrar general shows that the death rate of England and Wales during 1907 reached the remarkably low figure of 15 per thousand of the population. This is 2.4 per thousand lower than it was ten years ago; it is lower than for any other nation, except perhaps Sweden and Norway, though the lowest recorded death rates appear to be in Indiana and Michigan, where in 1905 they were 12.8 and 13.5, respectively. There is nothing more appalling than, and at the same time so hopeful as, the great differences in the death rates in different parts of the civilized world. It seems almost incredible that in one country or in one city twice as many people of each thousand inhabitants die as in others. We may sympathize with Tolstoy in his grief for the cruel executions that occur in Russia, but they are after all an insignificant matter compared with the fifty million people who have died needlessly in that country in the course of the past twenty-five years. But we need not go to Russia for a warning, when the death rate in New York is twenty per cent. higher than in London, when ten times as many in proportion to the population die from typhoid fever in Pittsburg as in New York, or when the death rate in one Massachusetts town is twice as high as in another.

It is gratifying that the infant mortality in England in 1907 was as low as 118 per 1,000 births, as compared with an average of 145 in the ten preceding years. But it is an ominous fact that the birth rate has fallen even more rapidly than the death rate. The birth rate in 1907 in England and Wales was 26.3, as much as 0.8 lower than in the preceding year and 10 lower than in 1876. If this fall should continue there would be no children born in England at the close of the present century. Absurd as this may appear, it is difficult to see why if the average family has decreased from four to three in the course of thirty years, it may not continue to decrease to two and to one.

On the other hand, the death rate can not continue to decrease indefinitely, and indeed it seems to have almost reached its minimum. When one thinks of the vast amount of intemperance, poverty and preventable disease in England, it might appear that there is room for endless improvement. But even a death rate of 15 is paradoxical. This means that only one person in 66.6 dies each year, and if the population were stationary the average duration of life would be 66.6 years. As one infant in seven dies, the average age at death of those who survive the first year would be 77, which obviously it is not, nor is likely to be. The paradox is explained by another paradox, namely, that a high birth rate tends to give a low death rate. Countries, cities and classes having a high birth rate usually have a high death rate and the infant death rate is nearly ten times the average; yet it is the high birth rate in England in past years which gives it its present low death rate.

If the birth rate of a country should

M. GABRIEL LIPPMAN.
The eminent physicist of the Sorbonne, to whom the Nobel prize in physics has been awarded.

suddenly increase, its death rate would also increase at first, owing to the high infant mortality, but in the subsequent fifty years the population would be composed largely of people between the ages of ten and fifty years, whose death rate is the smallest, and the death rate of the whole country would be low. Thus in England the greatly increased population of the country is due to the high birth rate in the sixties, seventies, eighties and nineties. Although the recorded birth rate was higher in 1876 than previously, this is probably due only to the improved registration. But the ever increasing population has given a composition such that those predominate in numbers who are at ages at which the death rate is low. Of a thousand people in France, about 125 are over sixty years of age, of a thousand in England only about 75 are of this age. The lower death rate in England is largely due to its more youthful population. It may decrease somewhat further, owing to improved hygiene and sanitation; but if the birth rate continues to decrease there will come a time when the death rate will increase.

ALBERT GAUDRY

In the loss of Professor Gaudry, who died recently in Paris, paleontology suffers not only in France but in the world at large, for he was an investigator of rare ability who was also gifted with a felicitous mode of expression. It is remarkable that his earliest work of note was also his greatest. This was the memoir on the fossil mammals of Pikermi, a small hillock of Upper Miocene age in Greece. Taken altogether, the volume on the Pikermi mammals is the finest contribution which has ever been made to the paleontology of the mammals in Europe, with the possible exception of Kowalevsky's great memoirs of 1873. Similar works appeared on fauna of the same age at Mt. Leberon. Gaudry's most popular volume was his "Enchainements du Mo de Animal."

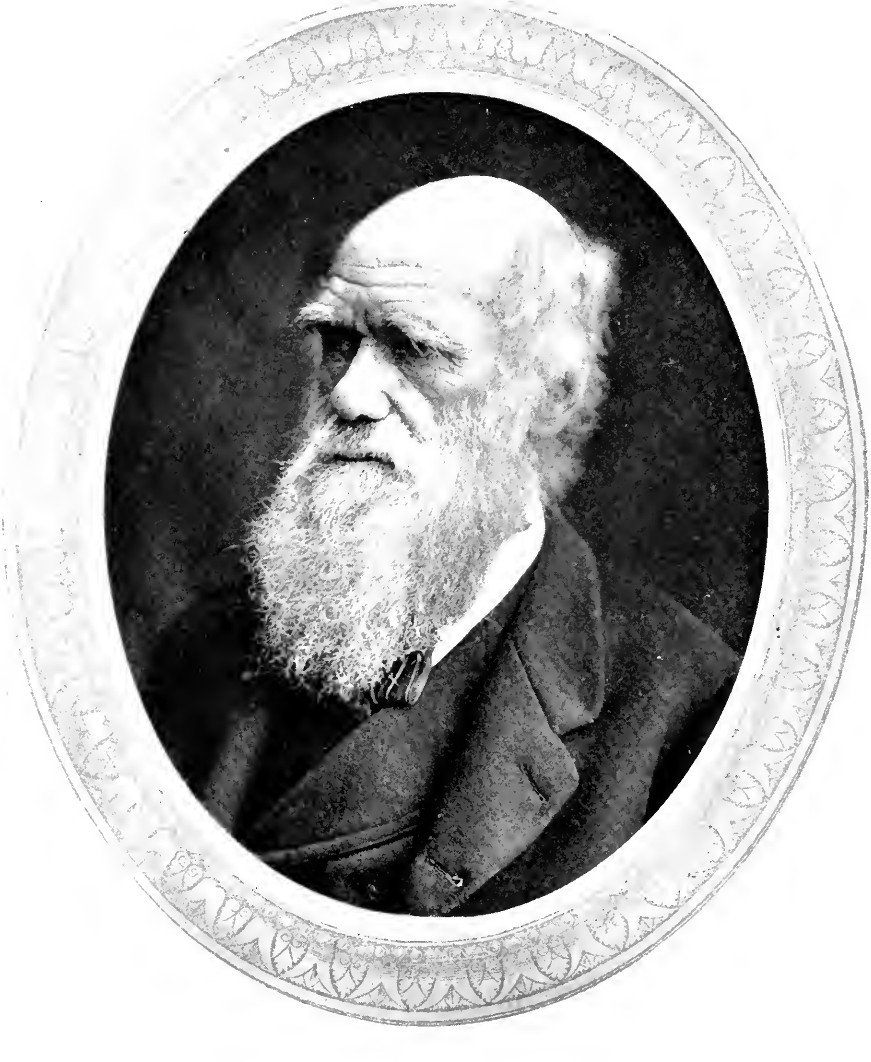
The most original feature of Gaudry's research on the Pikermi fauna was his recognition of the polyphyletic nature of the evolution of the horses, rhinoceroses and other animals whose remains are found in such profusion in this classic locality of Greece. Gaudry's other great service to science was the building up of the splendid collection in the Jardin des Plantes, Paris, and the artistic finishing of the famous "Gallerie de Palæontologie," which contains the older collections which have found their way to Paris, including the classic types of Cuvier and de Blainville.

Professor Gaudry was a man of charming character and personality, a French gentleman of the old school; extremely sympathetic in his relations with others, and cordially enthusiastic in recognition of their work. He always showed marked hospitality in his reception of visiting paleontologists to the Paris museum, and was warmly welcomed on his rare journeys to foreign countries.

SCIENTIFIC ITEMS

The Astronomical Society of the Pacific has awarded its Bruce gold medal for the year 1909 to Dr. G. W. Hill for distinguished services to astronomy.—The first award of the gold medal recently established by the Smithsonian Institution in memory of the late Secretary Langley has been made to Messrs. Wilbur and Orville Wright.—M. Henri Poincaré, the eminent mathematician and philosopher, has been received into the French Academy, taking the seat vacant by the death of the poet Sully Prudhomme.

Dr. S. Weir Mitchell celebrated his eightieth birthday on February 15, and Professor Ernst Haeckel his seventy-fifth birthday on February 16.



THE
POPULAR SCIENCE
MONTHLY.

APRIL, 1909

LIFE AND WORKS OF DARWIN[1]

By Dr. HENRY FAIRFIELD OSBORN
COLUMBIA UNIVERSITY AND THE AMERICAN MUSEUM OF NATURAL HISTORY

I

COLUMBIA UNIVERSITY is celebrating the hundredth anniversary of the birth of Darwin, the fiftieth anniversary of the publication of the "Origin of Species." In the year 1809 many illustrious men[2] were born, among them Darwin and Lincoln, one hundred years ago to-day, February 12. So widely different in their lives, Darwin and Lincoln were yet alike in simplicity of character and of language, in love of truth, in abhorrence of slavery, and especially in unconsciousness of their power. Both were at a loss to understand their influence over other men. "I am nothing and truth is everything," once wrote Lincoln. In concluding his autobiography Darwin wrote:

> With such moderate abilities as I possess, it is truly surprising that I should have influenced to a considerable extent the belief of scientific men on some important points. My success as a man of science has been determined as far as I can judge, by complex and diversified mental qualities and conditions. Of these, the most important have been, the love of science, unbounded patience in long reflecting over any subject, industry in observing and collecting facts, a fair share of invention as well as of common sense.

Lincoln's greatest single act was his death blow to slavery. Man had been fighting for centuries for his freedom, in labor, in government, in religion, and in mind. It is certainly notable that the final victory for bodily liberty was won during the very years which wit-

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[1] Address delivered at Columbia University on the one hundredth anniversary of Darwin's birth, as the first of a series of nine lectures on "Charles Darwin and His Influence on Science."

[2] Alfred Tennyson, Edgar Allen Poe, Felix Mendelssohn, Oliver Wendell Holmes, William Ewart Gladstone.

nessed the final emancipation of the mind. I do not see that Darwin's supreme service to his fellow men was his demonstration of evolution—man could have lived on quite as happily and perhaps more morally under the old notion that he was specially made in the image of his maker. Darwin's supreme service was that he won for man absolute freedom in the study of the laws of nature: he literally fulfilled the saying of St. John, "Ye shall know the truth, and the truth shall make you free."

When we look back upon the very recent years of 1858–59, the years of revolution, we see that we were far from free either to study nature or reason about it. Our intellectual chains were from the forges of theology both catholic and protestant. The Bible was read as a revelation of physical law rather than as an epic of righteousness and spiritual law. Theology while in power was itself in a most critical position, in a *cul-de-sac* of antagonism to reason and common sense, and this despite the warnings of Augustine and of Bacon. As early as the fifth century the wise theologian of Numidia had said:

> Leave questions of the earth and the sky and the other elements of this world to reasoning and observation. Perceiving that you are as far from the truth as the east from the west the man of science will scarce restrain his laughter.

Similarly, the great founder of the inductive method observed:

> Do not excite the laughter of men of science through an absurd mixture of matters human and divine. Do not commit the consummate folly of building a system of natural philosophy on the first chapter of Genesis or on the Book of Job.

It is difficult for the college student in this day of liberty, if not of license, to realize that, in the words of Lowell:

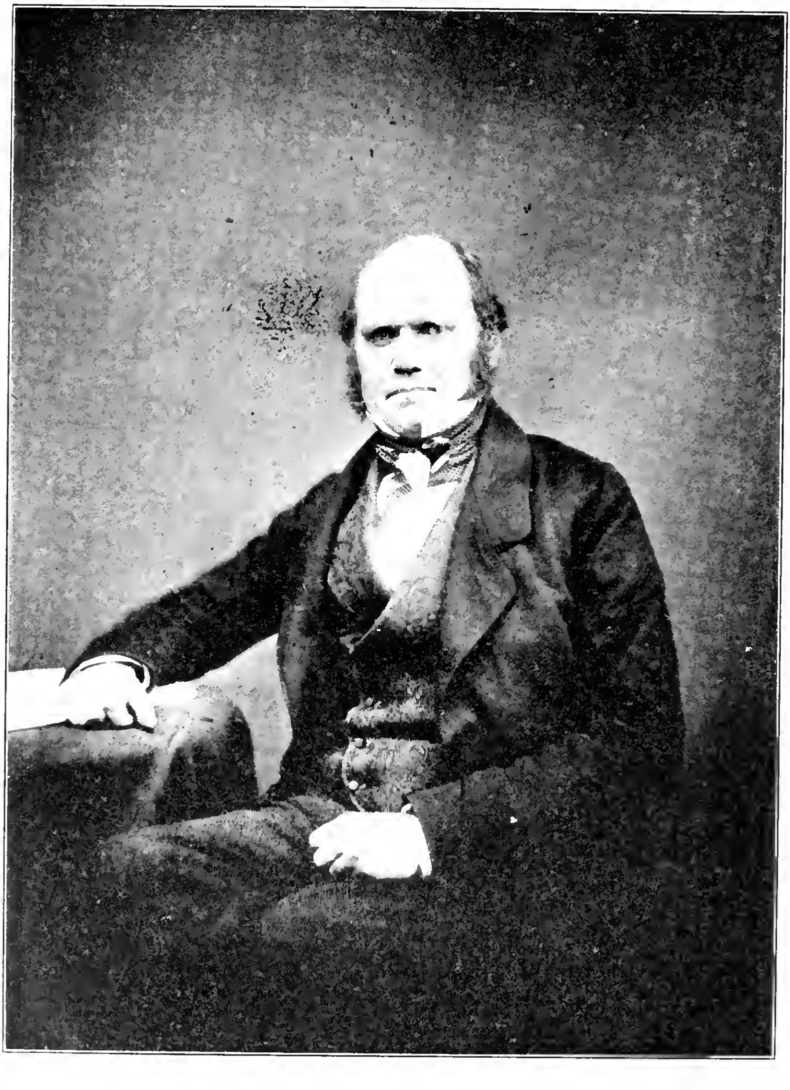
> We breathe cheaply in the common air thoughts that great hearts once broke for.

When, in 1844, Darwin communicated to the botanist Hooker under promise of secrecy his outline of evolution, he well knew the opprobrium it would bring, for he subsequently added (1846):

> When my notes are published I shall fall infinitely low in the opinion of all *sound* naturalists, so this is my prospect for the future.

From the borders of Poland in 1543, or just three centuries earlier, Copernicus had published his "Revolutions of the Heavenly Bodies," and thus fired the first shot in a three-hundred-years war for freedom to observe nature. In 1611 the telescope of Galileo demonstrated the truth of the Copernican law that the earth moves around the sun: and the most impressive object to-day in Florence is the model of the finger of this great astronomer as he held it up before the examiners of the inquisition, with the words, "It still moves."

As time advanced the prison gave way to the milder but effective



weapons of ostracism and loss of position. In biology Linnæus, Buffon, Lamarck, St. Hilaire, in turn discovered the evidences of evolution, but felt the penalty and either recanted or suffered loss of position. The cause of supernaturalism had never seemed stronger than in 1857; the masterly works of Paley and Whewell had appeared; the great series of Bridgewater Treatises to demonstrate the wisdom and goodness of God in the special creation of adaptations had just been closed; men of rare ability, Cuvier, Owen, Lyell and Agassiz, were on the side of special creation; yet at the very time this whole system of natural philosophy was rotten at the foundation because not the work of free observation.

Where his great predecessors Buffon and Lamarck had failed, Darwin won through his unparalleled genius as an observer and reasoner, through the absolutely irresistible force of the facts he had assembled and through the simplicity of his presentation. Lacking the literary graces of his grandfather, Erasmus Darwin, and the obscurity of Spencer, Darwin was understood by every one as every one could understand Lincoln. It is true the cause was immediately championed by able men, but victory was gained not by the vehement and radical Haeckel nor yet by the masterly fighter Huxley, but through the resistless power of the truth as Darwin saw it and presented it. It was not a denial, as had been the great skeptical movement of the end of the eighteenth century, but an affirmation. Darwin was not destroying but building; yet at the time good and honest men trembled as if passing through an earthquake, for in the whole history of human thought there had been no such cataclysm.

II

In what he achieved Darwin is so entirely alone that his place in the history of ideas is next to Aristotle, the great Greek biologist and philosopher who preceded him by over 2,000 years.

The biographers of Lincoln are at a loss to explain his greatness through heredity. Darwin belonged to an able family, and his ancestors are singularly prophetic of his career. He was near of kin to Francis Galton, who shares with Weismann the leadership in the study of heredity during the nineteenth century. By a happy combination of all the best traits of the best of his ancestors coupled with the no less happy omission of other traits, Darwin was a far greater man than any of his forebears. Kindliness, truthfulness and love of nature were part of his birthright. From his grandfather Erasmus, Charles may have inherited especially his vividness of imagination and his strong tendency to generalize. Countless hypotheses flitted through his mind.[3] "Without speculation there is no good and original ob-

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[3] "I can not resist forming one on every subject."

servation," he wrote to Wallace. Still more interesting is the fact that the inheritance of his grandfather's tendency toward speculation took the direction of evolution, for before the close of the eighteenth century Erasmus Darwin gave the world in poetical form his belief in a complete evolutionary system as well as the first clear exposition of what is now known as the Lamarckian hypothesis. But in the grandson hypotheses were constantly held in check by the determination to put each to the severe test of observation. Darwin speaks of his father, Robert, as the most acute observer he ever saw, and attributes to him his intense desire to understand the reasons of things; from him came caution and conservatism. He says in his "Autobiography":

> I have steadily endeavored to keep my mind free so as to give up any hypothesis (however much beloved), and I can not resist forming one on every subject, as soon as facts are shown to be opposed to it.

If the "poet is born not made," the man of science is surely both born and made. Rare as was Darwin's genius, it was not more rare than the wonderful succession of outward events which shaped his life. It is true that Darwin believed with his cousin Francis Galton that education and environment produce only a small effect upon the mind of any one, but Darwin underestimated the force of his educational advantages just as he underestimated his own powers, and this because he thought only of his book and classroom life at school, at Edinburgh and at Cambridge, and not of his broader life. It was true in 1817, as to-day, that few teachers teach and few educators educate. It is true that those were the dull days of classical and mathematical drill. Yet look at the roster of Cambridge and see the men it produced. From Darwin's regular college work he may have gained but little, yet he was all the while enjoying an exceptional training. Step by step he was made a strong man by a mental guidance which is without parallel, by the precepts and example of his father, for whom he held the greatest reverence, by his reading of the poetry of Shakespeare, Wordsworth, Coleridge and Milton, and the scientific prose of Paley, Herschel and Humboldt, by the subtle scholarly influences of old Cambridge, by the scientific inspiration and advice of Henslow, by the masterful inductive influence of the geologist Lyell, and by the great nature panorama of the voyage of the *Beagle*.

The college mates of Darwin saw more truly than he himself what the old university was doing for him. Professor Poulton of Oxford, believes that the kind of life which so favored Darwin's mind has largely disappeared in English universities, especially under the sharp system of competitive examinations; yet this is still more truly the atmosphere of old Cambridge to-day than of any of our American colleges. It would be an interesting subject to debate whether we

could nurture such a man: whether a Darwin, were he entered at a Columbia, a Harvard, a Princeton, could develop mentally as Charles Darwin did at Cambridge in 1817. I believe that conditions for the favorable nurture of such a mind are not with us. They are, repose, time for continuous thought, respect for the man of brains and of individuality and of such peculiar tastes as Darwin displayed in his avidity for collecting beetles, freedom from mental convention, general sympathy for nature, and above all ardor in the world of ideas. If the genial mind can not find the kindred mind it can not develop. Many American school and college men are laughed out of the finest promptings of their natures. In short I believe our intellectual environment would be distinctly against a young Darwin to-day.

Thus event after event in Darwin's life was singularly propitious. None but a Darwin would have reflected these events as he did, but grand and rare they certainly were.

At the age of nineteen he entered Christ's of Cambridge, the small college which two hundred years before had sheltered John Milton, the great poet of "Paradise Lost," the epic of the special creation theory which it was Darwin's destiny to destroy. His passion for sport, shooting, hunting, cross country riding, his genial enjoyment of friends of his own age, did not prevent delightful excursions with older men. He was known as "the man who walks with Henslow": and close personal intercourse with this learned and genial botanist (Rev. Wm. C. Henslow) affected him more than any other feature of his college life. After graduation this personal association extended through Henslow to the geologist Sedgwick, who prepared him for the next step in his career. It was Henslow who secured for him his place on the exploring ship *Beagle* and the voyage round the world (1831–1836), by far the most important experience in his life.

No graduate course in any university can compare for a moment with the glorious vision which passed before young Darwin on the *Beagle,* but here again fortune smiled upon him, for this vision required the very scientific spirit and point of view which came to him through the reading of the "Principles of Geology" of Lyell, the masterly teacher of the uniformitarian doctrine of Hutton. That nature worked slowly in past as in present time, and that the interpretation of the past is through observation of the present gave the note of Darwin's larger and more original interpretation, because the slow evolution which Lyell piously restricted to geology and the surface of the earth Darwin extended to biology and all living beings. If during the voyage Lyell's arguments convinced Darwin of the permanence of species, Lyell's way of looking at nature also gave him the means of seeing that species are not permanent. In his own words, he "saw through Lyell's eyes," and with the admiration of others always so characteristic of him his tribute to Lyell is without reserve. The second edition is dedicated:

> With grateful pleasure as an acknowledgment that the chief part of whatever scientific merit this Journal and the other works of the author may possess has been derived from studying the well known and admirable "Principles of Geology."

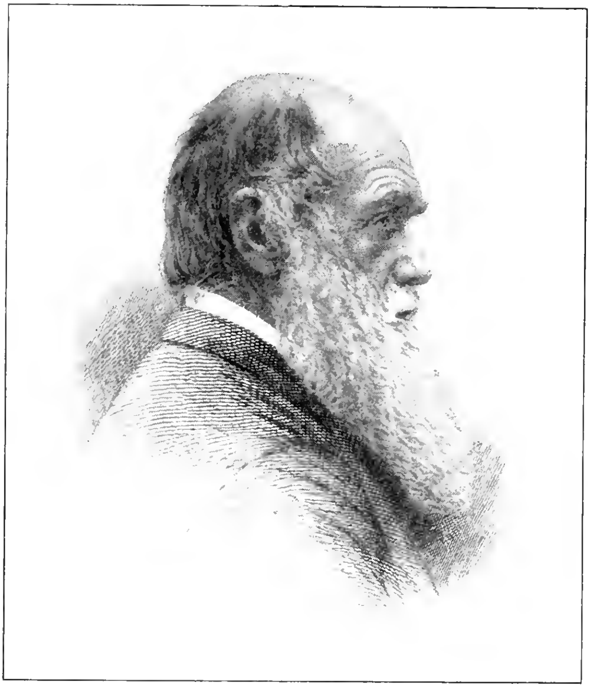
The five years of the voyage filled the twenty-second to twenty-seventh years of Darwin's life, the period now ordinarily given to professional studies. In reading this simply written but fascinating book, which stands quite by itself in literature, we see how Darwin through his own genius and through the methods successively impressed upon him by his father, by Henslow, by Sedgwick and by Lyell was unconsciously preparing his mind for the "Origin of Species" and the "Descent of Man," the two most influential books of science which have ever appeared. From the islands of the Atlantic and the Pacific we follow his delightful comments on animals and plants of all kinds on sea and land, through forests, pampas and steppes, up the dry slopes of the Andes, along the salt lakes and deserts of Chili and of Australia. The dense forests of Brazil pendent with orchids and gay with butterflies contrast with those of Terra del Fuego and of Tahiti, and with the deforested Cape de Verde Islands. On these islands, the first he visits, he is enormously impressed by the superiority of Lyell's method. He visits other islands of all kinds, inhabited and uninhabited, the non-volcanic St. Paul's rocks, half-submerged volcanic cones, coral reefs and islands of the south Pacific. He observes live glaciers, as well as the contrasting action of active and of dead volcanoes. Along the rivers of Patagonia he unearths great extinct or fossil mammals; in Peru he studies the extinct races of man; the aborigines of Terra del Fuego and of Patagonia make the most profound impression upon his mind. In brief, he sees the great drama of nature in all its lesser scenes and in all its grander acts. He begins the voyage a firm believer in the fixity of species, but doubts begin to enter his mind when in the sands of the pampas of South America he perceives that the extinct forms are partly ancestral to the living, and when on the isolated Galapagos Islands he finds the life is not that of a special creation but that detached from the continent of South America six hundred miles distant.

Darwin says:

> I owe to the voyage the first real training and education of my mind. That my mind had developed is rendered probable by my father's first exclamation on my return, "why the shape of his head is quite altered."

III

Soon after Darwin's return he moved to London for the two most active years of his life, to care for his collections and to write up his



observations. At this moment came the third of the great turning points in his life, which as a mysteriously disguised blessing was brought about through ill health. In London he was entering official duties and public scientific service which would undoubtedly have increased and interfered more and more seriously with his work. We can only count it as one of the most fortunate circumstances in the history of science that Darwin at the age of thirty-three was forced to leave London and to move to Down. Here for forty years he never knew for one day the health of an ordinary man; his life was one long struggle against the strain of sickness. But unrealized by him there was the compensation of a mind undisturbed by the constant interruption of outside affairs, such interruption as killed Huxley and is killing so many fine and ambitious men to-day. When I saw Huxley and Darwin side by side in 1879, the one only fifty-four, the other seventy, the younger man looked by far the more careworn of the two. Huxley, the strong man, broke down mentally at fifty-six; Darwin, the invalid, was vigorous mentally at seventy-two.

Darwin's writings fall into three grand series. In the nine years after he returned from the voyage, or between his twenty-seventh and thirty-sixth years, Darwin wrote the first series, including his pre-evolutionary geological and zoological works, his "Coral Reefs" (1842), his "Zoology and Geology of the Voyage of the *Beagle*" (1844–1846), his "Journal of Researches," the popular narrative of his voyage (1845). Darwin's ill health thereafter shut him off from geology, although his last volume, "The Earthworm," was in a sense geological.

It is characteristic of the life of every great man that his genius and his own self-analysis instinctively guide him to discover his mental needs.

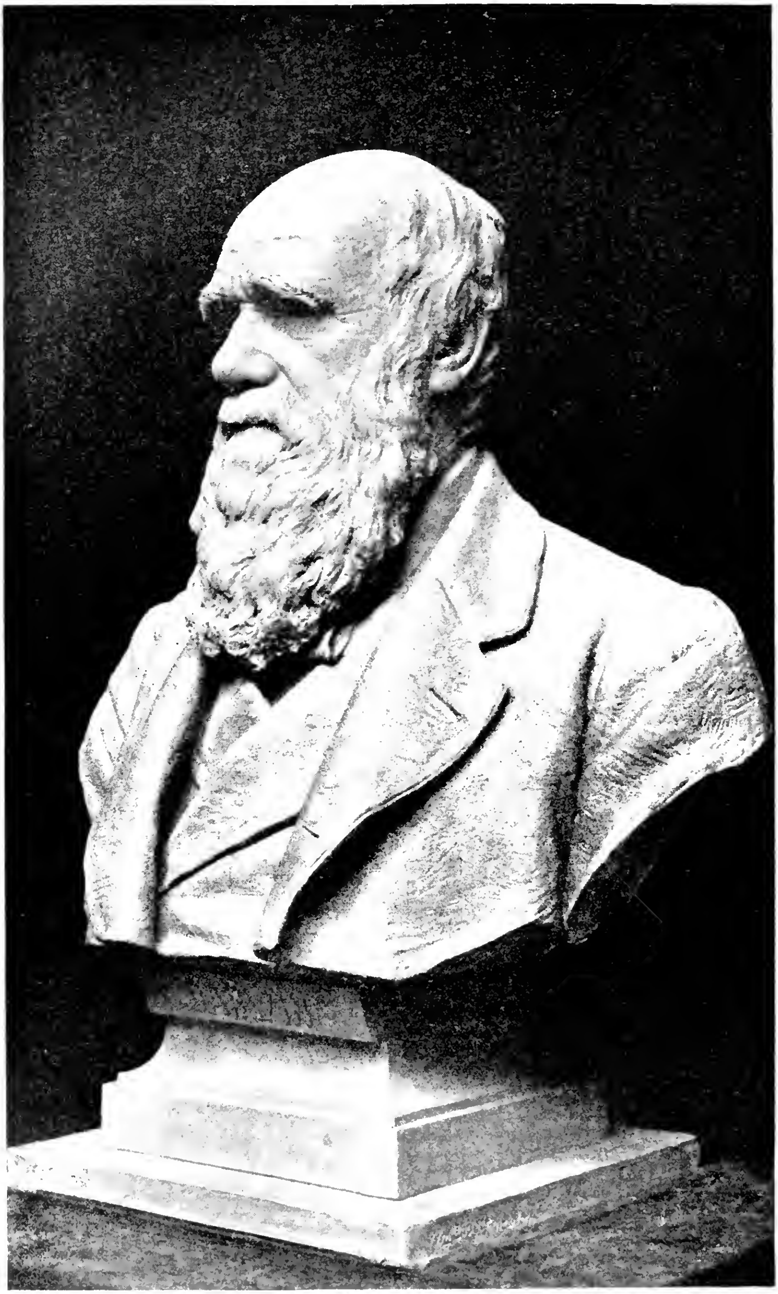
Until the age of forty-five Darwin in his own opinion had not completed his education, in the sense that education is a broad and exact training. He now proceeded to fill the one gap in his training by devoting the eight years of his life, between thirty-seven and forty-five, to a most laborious research upon the barnacles, or Cirripedia. This gave him the key to the principles of the natural or adaptively branching and divergent arrangement of animals through the laws of descent as set forth in the "Origin," which he certainly could not have secured in any other way. The value he placed on his work on the barnacles is of especial import to-day when systematic work is so lightly esteemed by many biologists, young and old. Darwin subsequently, in the words of Hooker, "recognized three stages in his career as a biologist, the mere collector at Cambridge, the collector and observer on the *Beagle*, and for some years afterwards, and the trained naturalist after, and only after, the Cirripede work."

Long before this, however, at the age of twenty-eight, Darwin had begun his career as a Darwinian. In July, 1837, he began his notes on the transmutation of species, based on purely Baconian principles, on the rigid collection of facts which would bear in any way on the variations of animals and plants under domestication and in nature. Rare as was his reasoning power, his powers of observation were of a still more unique order. He persistently and doggedly followed every clue; he noticed little things which escaped others; he always noted exceptions and at once jotted down facts opposed to his theories. On the voyage the marvelous adaptations of animals and plants had been his greatest puzzle. Fifteen months later, in October, 1838, in reading the work of Malthus, on "Population," there flashed across his mind the three-fold clue of the struggle for existence, of constant variability, and of the selection of variations which happen to be adaptive.

The three memorable features of Darwin's greatest work, "The Origin of Species," are, that he was twenty-one years in preparing it, that, although by 1844 he was a strongly convinced evolutionist and natural selectionist, he kept on with his observations for fifteen years, and the volume even then would have been still longer postponed but for a wonderful coincidence, which constitutes the third and not the least memorable feature. This coincidence was that Wallace had also become an evolutionist and had also discovered the principle of natural selection through the reading of the same essay of Malthus. It is further remarkable that of all persons Wallace selected Darwin as the one to whom to send his paper. It was then through the persuasion of the great botanist Hooker, who had known Darwin's views for thirteen years that these independent discoveries were published jointly on July 1, 1858. All the finest points of Darwin's personal character were displayed at this time; in fact, the entire Darwin-Wallace history up to and including Wallace's noble and self-depreciatory tribute to Darwin on July 1, of last summer, is one of the brightest chapters in the history of science. Wallace himself pointed out the very important distinction that while the theories contained in the two papers published fifty years ago were nearly identical, Wallace had deliberated only three days after coming across the passage in Malthus, while Darwin had deliberated for fifteen years. He modestly declared that the respective credit should be in the ratio of fifteen years to three days.

Several months past the age of fifty Darwin published his epoch-making work (November, 1859), and despite ill health, between fifty and seventy-three, he produced the nine great volumes which expand and illustrate the views expressed in "The Origin of Species."

A parallel to this remarkable late productiveness is that of Kant, who also put forth his greatest work after fifty. Let those past the five



decades take heart, for it appears that while there are inborn differences between men in this regard, imagination, observation, reasoning and production do not necessarily dim with age. Darwin's mind remained young and plastic to the end; his latest and one of his most characteristic works, "The Formation of Vegetable Mould through the Action of Earth Worms" was published at the age of seventy-two, after forty-four years of observation. It contained another and perhaps the most extreme demonstration of Lyell's principle that vast changes in nature are brought about by the slow operation of infinitesimal causes.

Three of Darwin's succeeding volumes are a filling out of the "Origin." "The Variation of Animals and Plants under Domestication" (2 vols., 1868) presents the entire fabric of the notes begun twenty-one years before on the transmutation of species. "The Descent of Man" (1871) was another logical outcome of the "Origin," yet it was only faintly adumbrated by a single allusion in that work to the fact that the transmutation of species necessarily led to the evolution of man. The "Descent" marks the third of the great dates in the history of thought, as the "Origin" marks the second, because it is the final step in the development of ideas which began with Copernicus in 1543. The world-wide sensation, the mighty *storm* produced by this bold climax of Darwin's work, is so fresh in the memory of all that a mere allusion suffices. The evolutionary or genetic basis for modern psychology as stated in "The Descent of Man" was given still more concrete form in Darwin's succeeding and most delightful volume "The Expression of the Emotions" (1872).

The knowledge of zoology and anatomy displayed in these four evolutionary volumes came from direct observation, vast and systematic reading and note-taking from the simple materials which Darwin could collect at Down. Always penetrating as these observations are, they are still, in my opinion, surpassed in beauty and ingenuity by his marvelous work on plants, published between 1862 and 1880. Here the principles of coadaptation of plants and insects in cross- and self-fertilization, in climbing plants and insectivorous plants, in forms of flowers, in movements of plants, are all brought forth in support of the theory of natural selection and the operation of unknown laws. Darwin's most precise observations and some of his most brilliant discoveries recorded in these volumes laid the foundations of modern experimental botany.

Of his method Darwin writes:

> From my early youth I had the strongest desire to understand or explain whatever I observed, that is, to group facts under some general laws. My mind seems to have become a kind of machine for grinding general laws out of large collections of facts.

The only work which Darwin wrote deductively was his "Coral

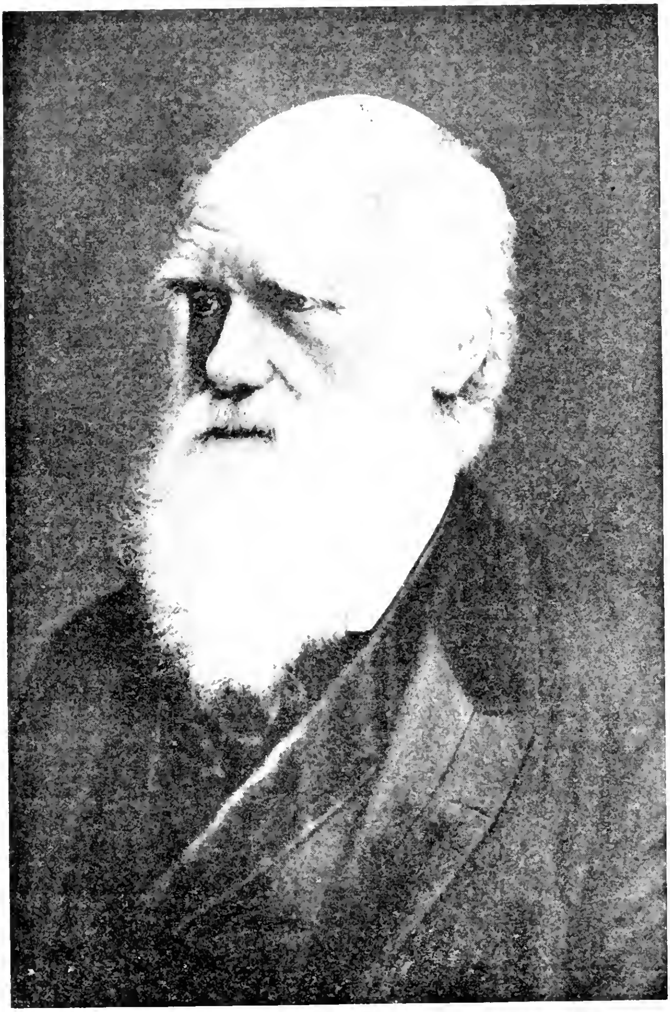
Reefs." Every other volume came through the inductive-deductive process, that is, through an early assemblage of facts followed by a series of trial hypotheses, each of which was rigidly tested by additional facts. The most central of these trial hypotheses was that of the building up of adaptations through the selection of the single adaptive variation out of the many fortuitous variations, and this Darwin was unable to rigidly test by facts but was obliged to leave for verification or disproof by work after him.

Darwin passed away in the year 1882, at the age of 73. Out of the simple and quiet life at Down he had sent forth the great upheaval and revolution.

IV

There is no denying that there is to-day a wide reaction against the central feature of Darwin's thought and this leads us to consider the merits of this reaction, as will be more clearly and fully set forth in the succeeding lectures of this series.

Now on this centenary when we are honoring Darwin, many may ask, exactly what is Darwinism? Failure to know leads some to doubt, others to predict a decline, especially where "the wish is father to the thought." Nothing could be less true than to say that there is the least abatement in the force of the main teaching of this great leader, namely, of the evolutionary law of the universe. The vitality of this idea is shown by its invasion of the physical world. Again, Darwinism is the sum of Darwin's observations on earth structure, on plants, animals and man. This vast body of truth and of interpretation still so far surpasses that brought forward by any other observer of nature, and these facts and interpretations are so far confirmed that they have become the very foundation stones of modern biology and geology. Finally, looking at Darwinism as the sum of his generalizations as to the processes of evolution we again find a vast body of well established laws which are also daily becoming more evident. As to the laws of evolution, there is no single biological principle more absolutely proved by the study of living and extinct things since Darwin's time than the broad law of natural selection: certainly the fittest survive and reproduce their kind, the fittest of every degree, classes, orders, genera, species, individuals and even the fittest organs and fittest separate parts of organs. Darwin still gives us the only explanation which has ever been suggested of hundreds of thousands of adaptations of which neither Buffon's view of direct effect of environment nor Lamarck's view of the inheritance of bodily modifications even approach an explanation worthy to be considered. Take the egg of the murre or guillemot, which is so much larger at one end than the other that it can not roll off the cliff on which it is laid, or the seasonal changes of color in the ptarmigan, every one of which is protective.



There is some lack of perspective, some egotism, much one-sidedness in modern criticism. The very announcement, "Darwin deposed," attracts such attention as would the notice "Mt. Blanc removed"; does it not argue courage to attack a lion even when deceased? Preoccupation in the study of one great law, as in the case of Bateson on Mendelism and De Vries on Mutation blinds to every other law. To be dispassionate, let us remember that Darwin's hypothesis was framed in 1838, seventy years ago. Are the two great Cambridge men, Newton and Darwin, lesser men because astronomy and biology are progressive sciences? Secondly, to know your Darwin you must not judge him by single passages but by all he wrote. Darwin is not to be known through the extremes of those of his followers with whom an hypothesis has become a creed. Reading him afresh and through and through we discover that his "variation" and "variability" are very broad and elastic terms. Every actual example he cites of his main hypothesis, such as the speed of the wolf, or the deer, or the long neck of the giraffe, is a variation both heritable and of adaptive value.

When we put together all the concrete cases which he gave to illustrate his views of selection we see that he includes both continuous and discontinuous variations, both the shades of difference of kind and proportion and the little leaps or saltations from character to character. For example, certain cases of immunity to disease are now known to be "unit characters" in Bateson's sense, or "mutants" in the De Vries sense. Darwin repeatedly referred to immunity as a variation which would be preserved by selection. Moreover, Darwin's own repeated assertion of his profound ignorance of the laws of variation certainly pointed the way to the investigation of these laws, and it is this very study which is modifying the applications of his selection hypothesis.

From first to last Huxley maintained that it would require many years of study before naturalists could say whether Darwin had been led to overestimate the power of natural selection. Darwin's mind from first to last was also open on this point. Through every edition of the "Origin" we find the passage:

> The laws governing the incipient or primordial variations (unimportant except as the groundwork for selection to act on and then all important) I shall discuss under several heads. But I can come, as you may well believe, to only very partial and imperfect conclusions.

In 1869 and in the latest edition of the "Origin" Darwin speaks of "individual differences" as of paramount importance, but he illustrates these differences by such instances as the selection of passenger pigeons with more powerful wings, or the selection of the lightest colored birds in deserts.

There can be no question, however, that Darwin did love his selection theory, and somewhat overestimated its importance. His conception of selection in nature may be compared to a series of concentric circles constantly narrowing from the largest groups down to the minutest structures. In the operations of this intimate circle of minute variations within organisms he was inclined to believe two things: first, that the fit or adaptive always arises out of the accidental, or that out of large and minute variations *without direction* selection brings direction and fitness; second, as a consistent pupil of Lyell, he was inclined to believe that the chief changes in evolution are slow and continuous. The psychology of the former is that he was in a reaction state from the prevailing false teleology. He was not expecting that purposive or teleological or even orthogenetic laws of variation would be discovered. William James has thus recently expressed and endorsed the spirit of Darwinism as a natural philosophy in the follow-words:

> It is strange, considering how unanimously our ancestors felt the force of this argument [that is, the teleological], to see how little it counts for since the triumph of the Darwinian theory. Darwin opened our minds to the power of the chance-happenings to bring forth "fit" results if only they have time to add themselves together. He showed the enormous waste of nature in producing results that get destroyed because of their unfitness.

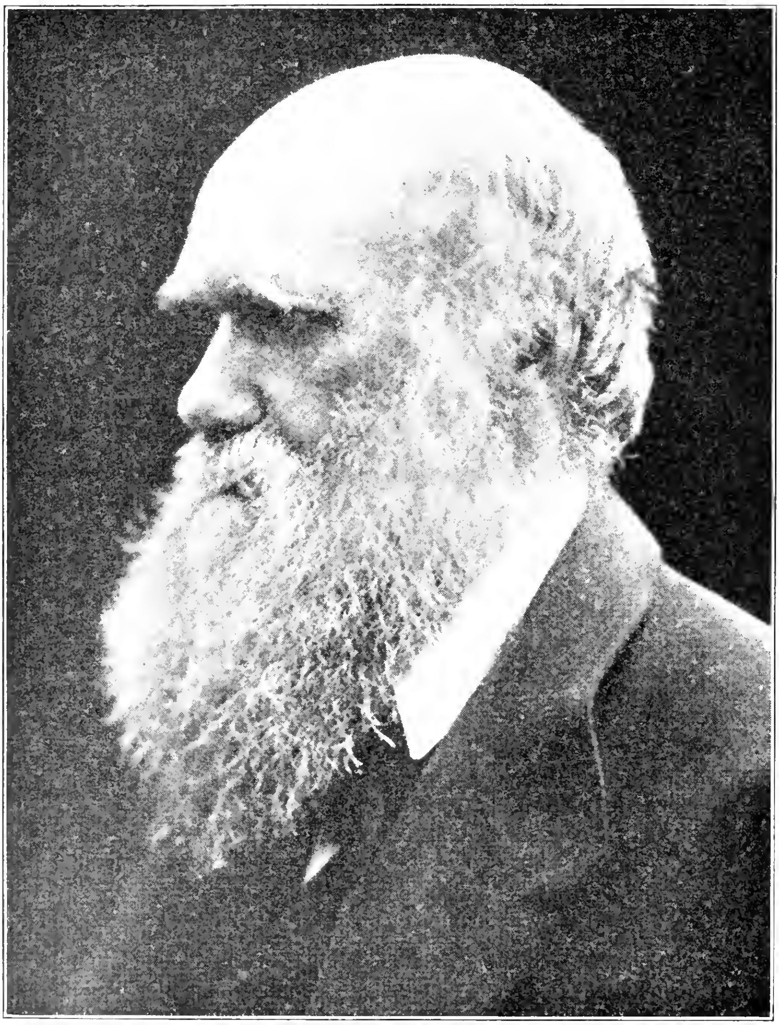
The simple question before us to-day and in the succeeding lectures of this course is: *is this true?* This really involves the deep seated query whether the intimate or minute parts of living things are operating under natural laws like non-living things, or are really lawless.

Before expressing my individual opinion based on my own researches of the last twenty years I may summarize the general modern dissent: in *three points* it may be said that Darwin's teachings are not accepted to-day.

First, his slowly developed belief in the inheritance of bodily modifications as well as the provisional "assemblage theory" of heredity which he called *pangenesis*, have been set aside for Weismann's law that heredity lies in the continuity of a specific heredity plasm, and for want of evidence of the transmission of acquired characters.

Second, while his prevailing belief that changes in organisms are in the main slow and continuous is now positively demonstrated to be correct by the study of descent in fossil organisms, there is also positive evidence for the belief which he less strongly entertained that many changes are discontinuous or mutative, as held by Bateson and De Vries.

Finally, his belief that out of fortuitous or undirected variations in minute characters arise direction, purpose and adaptation through selection still lacks proof by either observation or experiment. Fossil



and other descent series entirely unknown in Darwin's time certainly prove beyond question that law rather than chance is prevailing in variation.

What the nature of these laws is it is still too early to say. Personally I am strongly of the opinion that the laws of life, like the ultimate laws of physics, may ultimately prove to be beyond analysis.

To allow myself just one flight of fanciful statement drawn from personal observation and reflection I may say there is a likeness between the unit forces working in a single organism, both as revealed by the microscope and in fossil series, and the individual soldiers composing a giant army. The millions of well-ordered activities in the body correspond with the millions of intelligently trained men who compose the army; the selection process or the survival of the fittest is like the competition between two armies, between the Russian and Japanese, for example. It is an outward and visible competition between two internally prepared and well-ordered hosts of units and groups of units. Selection is continuously working upon the army as a whole and also upon every unit which affects survival—an immunity unit, an intelligence unit, a speed unit, a color or group of color units; just as in the army it is working upon units of courage, of strategy, of precision of fire, of endurance, of mass. In this sense it is perfectly true to say with Darwin "that selection works upon certain single variations." It is not true or at least it is not shown, that these variations are a matter of chance; they rather appear to be a matter of law as indeed Darwin foresaw when he stated that he used the word "chance" merely as a synonym of "ignorance."

In the present state of biology we are studying the behavior of the thousands of parts, sometimes of blending, sometimes of separate, sometimes of paired or triplicate units, which compose the whole and make up the individual organism. Natural selection determines which organism shall win; more than this, it determines which serviceable activities of each organism shall win. Here lie the limits of its power. Selection is not a creative principle, it is a judicial principle. It is one of Darwin's many triumphs that he positively demonstrated that this judicial principle is one of the great factors of evolution. Then he clearly set our task before us in pointing out that the *unknown* lies in the laws of variation and a stupendous task it is. At the same time he left us a legacy in his inductive and experimental methods by which we may blaze our trail.

Therefore, in this anniversary year, we do not see any decline in the force of Darwinism but rather a renewed stimulus to progressive search. As Huxley says:

> But tnis one thing is perfectly certain—that is, it is only by pursuing his method, by that wonderful single-mindedness, devotion to truth, readiness to sacrifice all things for the advance of definite knowledge, that we can hope to

come any nearer than we are at present to the truths which he struggled to attain.

V

On December 8, 1879, when Darwin was in his seventieth year and I in my twenty-second, I had the rare privilege of meeting him and looking steadily in his face during a few moments' conversation. It was in Huxley's laboratory, and I was at the time working upon the anatomy of the Crustacea. The entry in my journal is as follows:

> This is a red letter day for me. As I was leaning over my lobster (*Homarus vulgaris*) this morning, cutting away at the brain, I raised my head and looked up to see Huxley and Darwin passing by me. I believe I never shall see two such great naturalists together again. I went on apparently with skill, really hacking my brain away, and cast an occasional glance at the great old gray-haired man. I was startled, so unexpected was it, by Huxley speaking to me and introducing me to Darwin as "an American who has already done some good paleontological work on the other side of the water." I gave Darwin's hand a tremendous squeeze (for I never shall shake it again) and said, without intending, in an almost reverential tone, "I am very glad to meet you." He stands much taller than Huxley, has a very ruddy face, with benevolent blue eyes and overhanging eyebrows. His beard is quite long and perfectly white and his hair falls partly over a low forehead. His features are not good. My general impression of his face is very pleasant. He smiled broadly, said something about a hope that Marsh with his students would not be hindered in his work, and Huxley saying, "I must not let you talk too much,' hurried him on into the next room.

I may add as distinctly recorded in my memory, that the impression of Darwin's bluish-gray eyes, deepset under the overhanging brows, was that they were the eyes of a man who could survey all nature.

Another memory of interest is that the instant Huxley closed the door I was mobbed as the "lucky American" by the ninety less fortunate students of Great Britain and other countries.

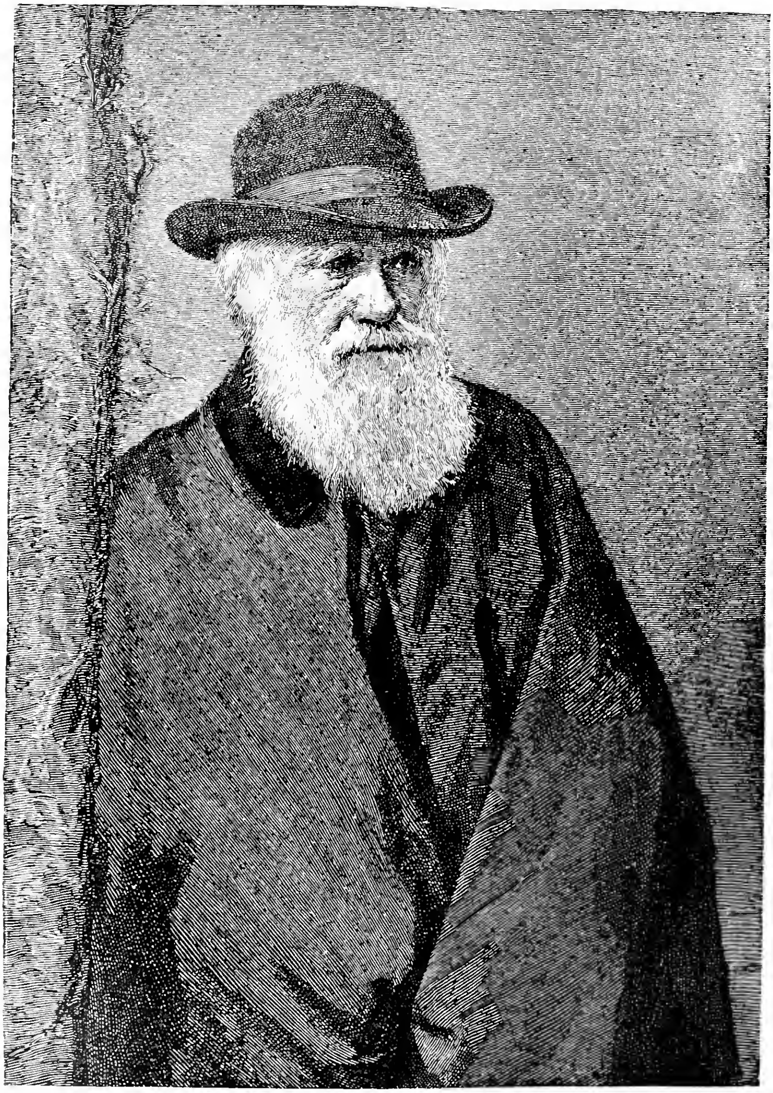
Huxley's solicitude for Darwin's strength was characteristic of him. He often alluded to himself as "Darwin's bull dog."

I have already stated that of the two men Darwin gave the impression of enjoying better health. Huxley was then sixteen years the younger, yet the burdens and strain of London life made him look less young and hale. In this connection an earlier jotting from the same laboratory is as follows:

> Huxley comes in as the clock strikes and begins to lecture at once, almost before it ceases. He looks old and somewhat broken, his eyes deeply sunken, but as a lecturer as strong as he ever could have been. His language is very simple too.

VI

What of the conflict between science and theology? We are now in a process of readjustment, but let us imagine our descendants in



Ch. Darwin

this university three or four hundred years hence looking back on the history of man. With larger perspective they will see two grand thought movements; the first, oriental, marked by oriental lack of curiosity about natural law, a great moral and spiritual movement developing along the Nile, the Tigris and Euphrates, out of five thousand years of hard human experience, culminating in Judea in the faith that nature is the continuous handiwork of God, in a supreme standard of righteousness, and in the simple expression of the human law "thou shalt love thy neighbor as thyself."

Another movement begins six centuries earlier in the inquiring mind of the west, always characterized by curiosity about nature. It was the search for natural law. Its rapid progress among the Greeks sadly terminates with the fall of Greece. After nineteen centuries it revives with Copernicus and Galileo and culminates in Darwin. Man is a part of nature; in the study of nature man finds intellectual delight; in the laws of nature man finds his physical welfare.

The conflict of opinion aroused by Darwin will subside like the evil passions of our Civil War. Surely the reverent study of nature can not lead man astray. These two great movements of love and of knowledge, first of the spiritual then of the intellectual and physical well-being of man, will be seen to be a harmony and not a discord.

THE INDIVIDUALITY OF CHARLES DARWIN

By CHARLES F. COX
PRESIDENT OF THE NEW YORK ACADEMY OF SCIENCES

WE are assembled, at the invitation of an organization devoted to the dissemination of scientific knowledge, under the hospitable roof of an institution maintained for the promotion of systematic observation, for the purpose of honoring the memory of one of the greatest of seers. Charles Darwin, whose birthday we celebrate, was a man of the clearest mental vision born into a generation scientifically blind. He first, of those in his day accounted wise, was able to see all nature unfolding according to uniform and verifiable law. The outlook of other men called by his contemporaries scientists and philosophers was, as a rule, limited and obscured by a narrowing and hampering doctrine of supernatural intervention. It is hard for us, who are privileged to contemplate with admiring minds the harmonious interrelations of all natural phenomena, to realize that only fifty years ago it was commonly regarded as both irrational and immoral to believe that one great principle underlay the origin, maintenance, diversification and development of living forms and that that principle was discoverable through human investigation. During the ages previous to the memorable year 1859 a few bold thinkers, now and then, had ventured to suggest a theory of general evolution, but they had failed to supply it with a substantial foundation of proof, or to assign to it a reasonable and intelligible cause, and had been, consequently, one and all, overwhelmed and suppressed by the powerful and prevalent dogma of special creation. Naturalists had been for centuries active in the collection of facts, but, until Darwin came, the various phenomena of living things remained disconnected and unexplained. Indeed, it was impossible that they should have been correlated and elucidated as long as the domain of science was in thralldom to tyrannical authority and originality of thought was little less than a crime. For a hundred years prior to Darwin even professed students of nature were not free to see what lay under their very eyes. The scientific world was awaiting a liberator. Finally the revolution was proclaimed and the first decisive blow struck by the publication of "The Origin of Species" on the twenty-fourth of November, 1859. It was no hasty and ill-considered

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[1] An address given at the American Museum of Natural History on February 12, on the occasion of the presentation of a bust of Darwin by the New York Academy of Sciences to the museum.

stroke. Events had been shaping themselves to this end since the twenty-seventh of December, 1831, when the little brig *Beagle* sailed from Plymouth harbor, bearing the unknown and youthful Charles Darwin to the discovery of a new world—not, however, an unexplored continent to be claimed for commerce and civilization, but a vastly greater and more valuable realm of thought to be opened to knowledge and conquered for intellectual freedom. Darwin, like the prophets of old, in preparation for his exalted mission, betook himself to the uninhabited wilderness, away from the influence of other minds, in order that he might draw inspiration from untrammeled and clarifying communion with nature. In his narrow cabin on the broad Atlantic, on the desert plains of Patagonia, on desolate and unpeopled islands of the Pacific, in the dark and solemn forests of the tropics, and on the summits of the bleak and barren Andes he gained the coveted prize of wisdom which had been denied him in the populous halls of two great universities where his free spirit had rebelled against the narrow conventionality of classical education.

Although a born investigator he had been driven and harassed for fourteen years by unthinking instructors devoid of both the ability and the disposition to consider his natural endowments and inclinations and who, with one or two exceptions, according to his own later judgment, wasted their time upon an unappreciative and discouraging pupil. He says of himself that he was slow in learning, but a review of his productive life clearly shows that, if he was dull in any respect, it was solely in the matter of accepting ideas at second hand. It happened, merely, that what most of his teachers were prepared to impart he was not constituted to receive; and so one of the acutest observers the world has ever known was thought to be inattentive and unreceptive. During all the school days of his childhood, passed in his native town of Shrewsbury, not only were his superb mental gifts wholly unrecognized, but no attempt was ever made to find out if he had any such gifts. He spent seven useless years at Dr. Butler's so-called "great school," but, apparently, the head master never came to know his talented pupil, for the educational system which prevailed in that institution had no reference to "the discovery of the exceptional man." The one ceaseless effort of his schoolmasters was to crowd him into the common mold.

Receiving no sympathy and little assistance from the teachers of his boyhood, he developed "a strong taste for long solitary walks" and cultivated the habit of stealing time for more or less surreptitious collecting in several departments of natural history. Thus he became, in all important respects, self-taught and, driven to his own resources, his natural inclination to consider his path of life as lying far aside from the common highway was confirmed and strengthened. This sense of solitariness followed him to the end of his life and was, no doubt, an important factor in the formation and preservation of his extraordinary individuality and faith in his own powers. Darwin's followers may therefore bless even the obtuseness and unwisdom of his preceptors who left him unspoiled by their restraining influence.

When, in 1825, Doctor Robert Darwin concluded that his son Charles was lacking in natural aptitude for scholarship, he sent him to Edinburgh University, intending that he should follow in the footsteps of his father and of his grandfather by becoming a physician. But here, again, the young man found himself unable to receive what was offered him on the strength of ancient authority. The instruction dispensed in that hoary institution was, to him, perfunctory and uninspiring and he was once more driven to seek the real enlargement of his knowledge by self-directed methods. In this way he appears to have obtained, at Edinburgh, some sort of acquaintance with the fundamental principles of scientific research, but, as the learning thus acquired was not in the line of his intended profession, it was not appreciated by his family and friends. Accordingly, after two sessions spent at that university, it was concluded that his regular studies had been entirely misdirected and he was therefore withdrawn and sent to Cambridge. There he was still worse misguided in the endeavor to educate him in theology. Again was repeated the old story of an uncongenial curriculum ostensibly conformed to but in reality shirked and avoided in favor of natural history privately followed by side paths. The unwilling student wished to be obedient to his father's direction, but native bent proved stronger than conventional rule—the call of destiny louder than the voice of filial duty.

His father, in most things a wise man, saw in his son's insect- and bird-hunting proclivity a tendency to the life of "an idle sporting man" and was sorely grieved and disappointed when he was obliged to concede the failure of his plan to connect the house of Darwin with the Church of England. Fortunately, however, the youthful Darwin came under the influence, at Cambridge, of a teacher endowed with more than ordinary discernment and, in this particular matter, with somewhat unusual independence and courage, and he took the budding naturalist and his lawless pursuits under his patronage and protection. To the faith and friendship of Professor J. S. Henslow Darwin was indebted for his appointment to the *Beagle* expedition, and to Professor Henslow, who robbed the church to enrich science, the world owes an incalculable debt of gratitude for the discovery, if not for the development, of one of its loftiest geniuses.

Others besides Henslow, however, had contributed to the fixation of Darwin's inborn talents and abilities, but Darwin never admitted that he received, either at Edinburgh or at Cambridge, anything like systematic mental training. He was, from the beginning of his school days to the end of his university life, a person set apart for individual preparation for a special and peculiar career. When he bade farewell to Christ's College, Cambridge, in the summer of 1831, his actual education was yet to be acquired, but not through human instruction. He has himself declared: "I have always felt that I owe to the voyage the first real training or education of my mind."

It was therefore no professional scientist who eagerly accepted the unsalaried post of naturalist to the *Beagle* expedition around the world, but a modest, though confident, youth of twenty-two whose most important article of outfit was the first volume of the first edition of Lyell's "Principles of Geology," which had been published the year before, the second volume of which was not issued until after Darwin had reached South America. Thus it was providentially ordered that during the formative period covered by this epoch-making voyage, Darwin should remain as free as possible from human influences. If, instead of proceeding, raw as he was, directly from the seclusion of the university to the isolation of the voyage, he had directed his steps to the metropolis and had there mingled with the leaders in scientific thought, it is quite possible, if not probable, that he would have fallen under their authority and would have accepted the orthodox beliefs of his time. If that had been the case, we might be dominated to-day by the prohibitive doctrine of the immutability of species, instead of enjoying that freedom of thought and liberty of investigation to which Darwin made us heirs. But, happily for the intellectual world, during the five years which Darwin spent on the *Beagle,* under the intimate tutelage of mother nature, he laid, for our benefit, as well as for his own, the solid foundations of that never-failing habit of mind in which open-eyed teachableness ever supplemented unwavering honesty of purpose and fearlessness of approach.

After Darwin's return from the circumnavigation of the globe, he resided, for a little more than five years, in London, and that was the only portion of his life during which he was in actual personal contact with any considerable number of his fellow men. Even then, however, he was mostly engaged with his own thoughts, for he was arranging his collections and preparing for publication the results of his observations made while on the *Beagle* voyage. It was at the very beginning of this residence in London (July, 1837), while the things he had seen in South America and the Pacific Islands were still fresh in his memory that he opened his first note-book for facts in relation to the origin of species, about which he says he "had long reflected." For twenty-two years thereafter Mr. Darwin continued to pursue this revolutionizing subject with unexampled patience and, except as to two or three intimate friends, entirely within the privacy of his own mind.

In September, 1842, he went into retirement at Down, an out-of-the-way village in Kent. There, partly compelled by ill-health, he dwelt as a recluse for forty years, serenely contemplating nature and diligently gathering information, but seldom emerging into the world from which his richly-stored and phenomenally creative intellect had little to gain, but to which it never ceased to give, during the remainder of his life. Bare knowledge he welcomed from any source, but opinions and deductions he invariably produced for himself. What he wrote to H. W. Bates, who complained of a want of advice, is true of Darwin himself: "Part of your great originality of views," he said, "may be due to the necessity of self-exertion of thought." What has been said by his son Francis is equally true of Mr. Darwin—one of his most striking characteristics was "that supreme power of seeing and thinking what the rest of the world had overlooked."

Mr. Darwin was what we are accustomed to call a genius, but I know of no good definition of a genius but *a man of insight*. The person who by his unaided mental vision is able to see into and through problems which to other men are baffling or insoluble, has the highest right to be considered inspired. Darwin's wonderful endowment in this respect constituted him, by divine right, a leader of men. The world has always justly honored its standard bearers and we are here to pay homage to the name of one of the most attractive and commanding of them all. In other parts of this city and of this land, our fellow-citizens are gathering to-day to pay grateful tribute to the estimable character, and to recall the memorable deeds of a great emancipator. We likewise are celebrating the beneficent acts of a man, simple and modest as that other, who, at a critical period, spoke courageous words which conferred freedom on millions of his fellow creatures. It is altogether fitting that the birthdays of these two benefactors should be the same.

We now dedicate this monument in this approprite place not only to the honor and memory of Charles Darwin the great thinker, whose life and personality we admire, but also to the encouragement and guidance of all who may hereafter frequent these halls—as a testimony to the power of self-reliance and independence of mind which Charles Darwin preeminently exemplified and illustrated. May this portrait of a noble truth-seeker which we now unveil, signify, for all time to come, to him who would advance the boundaries of scientific knowledge that nature will yield up her secrets only when appealed to directly and in humility and purity of spirit.

DARWIN AND GEOLOGY[1]

By Professor JOHN JAMES STEVENSON

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CHARLES DARWIN was born in a time of intellectual unrest. Explorers, students of chemistry and workers in mines had been adding to actual knowledge for nearly one third of a century and thoughtful men had been forced to recognize the worthlessness of many conceptions which had long passed current. Nowhere was this unrest more manifest than among the younger geologists; but they were compelled to express themselves cautiously, for, fettered by a false chronology, the church dignitaries who controlled the universities rebuked investigation and branded as infidels those who recorded obnoxious facts. Little more than a year prior to Darwin's birth, the Geological Society of London had been founded as a protest against subjective study of this globe, but already many adherents to the principles of that society had appeared on the continent, proclaiming that actual knowledge of conditions must precede attempts to explain them.

The development of opinion was so rapid that before Darwin reached his majority the geological pendulum had made its great swing from the doctrine of cataclysms to that of uniformity; from the belief that this globe is less than 6,000 years old to an abiding faith that its age can not be measured in years. It was amid such conditions that toward the close of his university studies, he came under the influence of Henslow and Sedgwick, the latter being engaged at that time along with Murchison in an effort to unravel the tangle of Welsh geology. Some have said that these men taught him how to observe; not so; he was already a keen observer and they merely led him into wider fields.

In 1831, Captain Fitzroy was assigned to command H. M. S. *Beagle,* a little brig of 240 tons, and was commissioned to complete the coast survey of southern South America as well as to run a line around the globe. When he expressed the wish to be accompanied by a naturalist, Darwin, then only twenty-two years old, promptly volunteered his services, which were accepted, and he was enrolled as a supernumerary member of the staff. The *Beagle* left England on December 27, 1831, and returned on October 2, 1836, bringing with it Charles Darwin, now grown intellectually to man's stature and bearing a notable cargo of material collections as well as of accumulated observations. There

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[1] An address given at the American Museum of Natural History on February 12.

was no haste in publication; aside from some very brief communications to societies, nothing appeared until 1839, when the *Journal of Researches* was printed. Owen's descriptions of the fossil mammalia was issued in 1840 with an introduction by Darwin and the final publication of results was made in three parts, dated 1842, 1844 and 1846. Thus early in his career, Darwin showed that caution which characterized him throughout life, an indifference to priority which was the outgrowth of his love of accuracy.

Part 2 of the "Geological Observations," dated 1844, relates chiefly to volcanic islands. In most cases the stay at those was brief and the studies were fragmentary; yet Darwin saw enough to let him discuss the origin of volcanic cones, to determine some cardinal points respecting the distribution of the islands, to distinguish submarine from subaerial lava flows and to prove that experimental studies on metamorphosis of limestones had led to very nearly true conceptions of the process.

As the coast survey of southern South America was the important object of Captain Fitzroy's expedition, there was ample time for a good reconnaissance of that region and Darwin spent nearly six months in studying the pampas from the Parana and Uraguay rivers southward almost to Magellan's Strait. A synopsis was given as an introduction to Owen's Memoir, but the details did not appear until 1846, when they were published as Part 3 of the "Geological Observations." The whole subject was discussed attractively in the second edition of the *Journal of Researches.*

The superficial deposit of the great plains is a "reddish argillaceous earth" containing concretions of indurated marl, which at times become continuous layers or even replace much of the red earth. In the northerly part of the plains-area, this pampas deposit, which passes downward into sands, limestones and clays of late Tertiary age, yielded no marine shells to Darwin; its infusoria, studied by Ehrenberg, proved to be partly marine, partly freshwater, while the marly concretions resemble some freshwater limestones seen in Europe; but this paucity of invertebrate life was unimportant, for the whole of that region proved to be one vast cemetery, in which the skeletons of gigantic extinct mammals are so numerous that a line could not be drawn in any direction without passing through some bones. In northern Patagonia the red deposit is bound closely to an overlying gravel, containing marine forms belonging to species now existing on the coast, while in southern Patagonia marine shells occur in the pampas deposit itself.

Darwin believed that this pampas material was deposited within a vast estuary, into which great rivers carried from the surrounding region carcasses of the animals whose skeletons were entombed in muds tranquilly accumulating on the bottom. All conditions go to show that the mammalia became extinct after the sea had received its present fauna; and there is nothing to suggest that a period of overwhelming violence swept away and destroyed the inhabitants of the land; everything supports the contrary belief. The only noteworthy change in conditions has been a gradual elevation of the continent; but that was not enough to modify the climate or to bring about a change in the land fauna.

Several of the important genera collected by Darwin had been found in North America long prior to his time. This similarity of the Quaternary faunas induced him to speculate on the causes which had divided the American continent into two well-defined and somewhat contrasting zoological provinces. He does not hesitate to suggest recent elevation of the Mexican platform or more probably, recent submergence of the West Indian Archipelago as a conceivable cause of this separation. It seems to him most probable that the elephants, the mastodons, the horses and the hollow horned ruminants of North America "migrated, on land since submerged near Behring Straits, from Siberia into North America, and thence, on land since submerged in the West Indies, into South America, where for a time they mingled with forms characteristic of that southern continent and have since become extinct." Had this American Museum of Natural History existed in Darwin's day, study of the remarkable exhibits in its Mammalian Hall would have enabled him to extend his list of extinct forms common to both continents, and possibly he might have anticipated some of the all-important generalizations for which the world is indebted to the former president of this academy, who now is president of the museum.

Nothing in South America, east or west, escaped Darwin; from glaciers to peat bogs, from earthquakes to climatal variations, everything was important; but what impressed him most on both sides of the continent were the evidences of extremely slow secular movement in the earth's crust. This was the preparation for that study of the coral islands which resulted in his chief contribution to philosophical geology.

Many voyagers prior to 1833 had observed and had tried to account for the strange atolls, or low ring-like coral reefs, each enclosing a lagoon which communicates with the sea by a narrow channel; but Darwin discovered other forms of reefs which were equally perplexing. Many islets of rock are fringed by coral growth, while vast barrier reefs, separated from the land by channels of varying depth, extend at times for hundreds of miles along coasts. All explanations by previous observers were defective as they seemed to ignore these types as well as other features, not less important.

Reef-making corals can not endure exposure to the air and they can not thrive at a depth of more than 20 fathoms, so that their vertical range is about 115 feet; yet hooks and anchors brought up coral rock and sand from many hundreds of feet below the limit of growth; in a great number of instances, the atolls or ring-like reefs are mere peaks rising with abrupt slopes from "fathomless" abysses. Coral-bearing areas within the Indian and Pacific Oceans are of vast extent, there being chains of archipelagos, 1,000 to 1,500 miles long. The reefs are rudely circular or elliptical in the islands but are linear along the coasts; in the one case, the reef encloses a lagoon, in the other, a lagoon-like channel separates the reef from the coast. These are fundamental elements of the problem, not one of which may be neglected in the solution. A clue to the explanation was found by this keen observer when he saw an islet of old rock, fringed with coral, rising from the lagoon of an atoll, so that the atoll-ring resembled in many respects the barrier reef of a continent and the lagoon itself resembled the lagoon-like channel seen on the Australian and other coasts.

Chamisso's suggestion that coral reefs had been formed on banks of sedimentary material seemed wholly incompetent to meet the conditions, for the areas are too vast, and Darwin was compelled to believe that the atolls rest on rocky bases; but even on this supposition, it appears incredible that peaks of several great mountain chains should all come to within less than 180 feet of the surface and that not one rose any higher. The long study in South America had prepared him to seek an explanation in mobility of the earth's crust; but it was clear that elevation could not bring about the conditions, as that would destroy the corals themselves; subsidence alone can account for the phenomena. And thus Darwin presents his case:

> If then the foundations of the many atolls were not uplifted into the requisite position, they must of necessity have subsided into it; and this at once solves every difficulty, for we may safely infer from the facts given in the last chapter, that during a subsidence the corals would be favorably circumstanced for building up their solid framework and reaching the surface, as island after island slowly disappeared. Thus areas of immense extent in the central and most profound parts of the oceans might become interspersed with coral islets, none of which would rise to greater height than that attained by detritus heaped up by the sea, and nevertheless they might all have been formed by corals which absolutely require for their growth a solid foundation within a few fathoms of the surface. . . . The rocky bases slowly and successively sank beneath the level of the sea, while corals continued to grow upward.

The origin of the ring as well as that of the barrier reef seemed to be easily explained by this hypothesis. The corals on the outer side of the reef grew with greater rapidity than did those within, as the supply of food is constant; those on the inner side became starved and eventually the interior growth ceased and the lagoon was shallowed by wind-drifted material from the shores.

Darwin's hypothesis and the facts on which it was based have become so familiar that students sometimes express surprise that so much praise has been awarded to the author. The conditions as presented in his discussion are so clear that certainly no man could reach any other conclusion. That is true, but it is true only because Darwin marshalled his facts in a manner so masterly; in any event, it is always easy to do a thing when another has done it well and told us how. But it must be remembered that an hypothesis of this sort, though normal enough in our day, was very abnormal in that day; indeed, it was contrary to Darwin's own underlying conceptions, for, though a uniformitarian, he had seen many phenomena which, for a time, made him only a halting disciple. Yet his hypothesis was a monumental contribution in support of the uniformitarian doctrine, which, under the leadership of Lyell, was gaining sturdy adherents. That the hypothesis met with uncompromising opposition need not be said. The material of coral origin extended to vast depths alongside of the islands, in some cases apparently to 4,000 feet. The upward growth of the reef was known to be extremely slow. If the subsidence and the upward growth kept pace, as was essential to the hypothesis, evidently the required period, belonging to the latest portion of the earth's existence, was immensely long. It is difficult now to understand how great moral courage was needed by the man who published such a doctrine; sixty years ago, the educated man of Great Britain had not learned to distinguish between faith and prejudice.

This effort to explain the origin of coral reefs has been regarded, justly, as Darwin's especial contribution to geology. It has been opposed strenuously by careful students during the last twenty years and even now it is a bone of contention; but the most strenuous opponent concedes that it is logical and a fair induction from the facts as then known. Be it true or not, be it a competent explanation or not, no matter. In influence on geology it has been as far-reaching as the doctrine of natural selection has been on biology. It involves every important problem in dynamics of the earth's crust; in testing it, men have been led into paths of investigation, which, but for Darwin, might still be untrodden. The influence went farther. The hypothesis was presented at a time when men's minds were warped by prejudice, when men were extremists, when too many were defenders of dogmas in science and too few were searchers after truth. Darwin's discussion was a model of frankness; suggestions offered by his predecessors were dealt with courteously; he searched far and wide for objections to his own suggestions, and when objections were found he stated them in detail, concealing nothing and urging further investigation. His conclusions were, for him, merely tabulations of observed facts. One can not overestimate the importance of this method; it was a chief factor in changing the tone of scientific literature, in leading to replacement of subjective by objective modes of investigation.

Darwin's work as geologist practically ended with these publications of the *Beagle* results. It is true that in later years he made some contributions possessing much interest, but they were merely incidental to studies in other directions; the greater part of his long life was devoted to biological problems. At the same time, his whole mode of thinking and of observing was that of the geologist, so that if one were treating of his later years the topic might well be the influence of geology upon Darwin. In his later works, one finds constantly recurring consideration of geological conditions as potent factors in biological change, while on the other hand he emphasized the influence of life as a factor in bringing about geological changes. To him nature was always one; and he, in great measure, was responsible for the broadness of view characterizing the geologists who were his contemporaries as well as for the remarkable change in attitude of the community toward scientific discussion. Nowadays, when workers are so many and knowledge is so increased, men have been forced into narrow lanes of investigation; students, perplexed by phenomena within their limited vision, too often think little and know less of what neighbors are doing. And this must continue until some important problems have been solved, at least in part, and some positive results have been obtained in many directions. Then another Darwin will come, will gather loose strands floating in the wind and will weave from them a new system, once more binding nature studies into one and providing a safe platform, whence men may start anew to fathom the unknown by means of the known.

DARWIN AND BOTANY[1]

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CONSIDERING the fact that Charles Darwin disclaimed the title of botanist, his contributions to the knowledge of plant life and its phenomena were certainly extraordinary. His investigations extended over a great range of topics, at one time or another practically covering the whole field of botanical research. In repeatedly stating that he was not a botanist, he evidently meant to imply that he was not a systematist, and it is true that his knowledge of plant taxonomy was the least of his scientific acquirements. In his first letter to Dr. Asa Gray, written in 1855, which was the commencement of a long correspondence, he almost apologized for asking questions! During that year he became keenly interested, however, in knowing more about the kinds of plants growing wild in the vicinity of his home, and in a letter to Dr. Hooker he complains about the dreadful difficulty of naming plants, though he apparently became quite enthusiastic in this pursuit and advised Dr. Hooker, "If ever you catch quite a beginner and want to give him a taste of botany tell him to make a perfect list of some little field or wood." The facts just stated seem to indicate the extent of his taxonomic studies. He accepted, for the most part, the names of plants which he studied from the determinations of others.

Darwin was attracted to observations of natural objects as a young boy and he early considered plants; his juvenile collections were entomological, and his earlier investigations were mainly zoological and geological. As a pupil of Professor Henslow at Cambridge University he attended botanical lectures and took part in field excursions; he greatly enjoyed the field work, and from it his inspiration for investigation was doubtless derived.

As naturalist of the voyage around the world of the ship *Beagle* (1831–1836) his collections of plants made in South America and on the islands of the Pacific Ocean, and his observations upon the botanical features of the countries visited, contributed greatly to the knowledge of the flora of those regions. They were extensively utilized by Dr. Hooker in his "Flora Antarctica" and in his "Flora of the Galapagos Archipelago," as well as by other authors in various contributions. Darwin's valuable herbarium is preserved in the museum of Cambridge

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[1] An address given at the American Museum of Natural History on February 12.

University. That he collected assiduously at times during portions of this expedition, is evidenced by his having brought home specimens of 193 species of the 225 species which, after his specimens had been studied, were known to inhabit the Galapagos Islands and by the fact that about 100 species new to science were represented in his Galapagos collection. He noticed the extraordinary distribution of species or races on the several islands of this group, many of them inhabiting only a single island, and he laid the foundation for all subsequent study of insular floras. The narrative of observations and experiences during this memorable voyage is replete with interesting facts and suggestions concerning plants, and his conclusion that "Nothing can be more improving to a young naturalist than a journey in distant countries," is one that should be reiterated by all teachers of natural science, and such experience should be sought by all students who propose engaging in investigation. Darwin is commemorated in botanical taxonomy by many species named in his honor. The beautiful barberry, *Berberis Darwinii* of Hooker, native of Chiloe, is occasionally seen in cultivation. *Darwinia,* an Australian genus of the myrtle family, named by Rudge in 1813, commemorates his grandfather, Erasmus Darwin.

The beginnings of Darwin's theory of descent of animals and plants from preexistent species, with modifications, were made during the voyage of the *Beagle,* and from the year after his return to England, when, he tells us, he opened the first note-book on the subject. For twenty-two years he was interrogating gardeners and breeders, botanists and zoologists, and diligently observing plants and animals. He first thought of publishing on the theory of descent in 1839, but delayed for twenty years. During the studies which led up to the publication, in 1859, of "The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life," Darwin closely observed a great number of wild and cultivated plants, with reference to variation in nature and under domestication, the struggle for existence due to competition for food and sunlight, the facts of geographic distribution, the succession of plant life on the earth as indicated by the fossils of successive geologic periods, and a great range of other facts and phenomena. The recorded observations of other botanists were also freely utilized and discussed. Nearly all the chapters of this epoch-making work contain conclusions drawn from his own botanical observations. He was especially impressed by the divergent views of different botanists relative to the taxonomic treatment of highly polymorphic genera such as *Hieracium* (hawk-weeds), *Rubus* (blackberry), *Quercus* and *Rosa,* and he employed this consideration to great advantage in his argument for derivation during descent. Rudimentary organs were considered with much interest and readily explained by Darwin as vestiges of structures which were useful to the plant in earlier stages of its existence. The facts of geographic distribution were eagerly examined as bearing on the theory of descent and Darwin's writings abound in speculations relative to their significance. He was inclined to combat the geologic theory of former land connections of present existing continents, as not satisfactorily accounting for many features of geographic distribution, though he ultimately agreed with this theory to some extent. He closely studied the natural means by which seeds are transported over great distances and also inquired into the vitality of seeds.

The title of the "Origin" was a subject of considerable doubt in his mind, and in 1857, two years before it was printed, he had proposed to call it "Natural Selection." The title "Origin of Species by Means of Natural Selection," is, if taken literally, somewhat misleading, and has occasioned considerable discussion. The subtitle—"Or the Preservation of Favored Races in the Struggle for Life"—is a more accurate statement of his theory. On November 23, 1856, he wrote to Dr. Hooker:

> The formation of a strong variety, or species, I look at as almost wholly due to the selection of what may be incorrectly called chance variations. Again, the slight differences selected, by which a race or species is at last formed, stand, as I think can be shown in the far more important relation to its associates than to external conditions.

Darwin's great contribution to the subject of evolution was the incontrovertible proof adduced by him that living species are modified descendants of preexisting species, and that the modifications are brought about by natural causes. His observations led him to the conclusion that the modifications were all minute, gradual and cumulative. We know that they may also be considerable and abrupt and that they are cumulative because favorable changes are preserved.

How, then, do the modifications or primordial variations, either large or small, arise? Is variation an innate essential quality, or is it induced by external environmental factors? Proof of environmental agencies having at least something to do with it in plants seems to be accumulating, as the experimental work carried on by MacDougal and by Gager at the New York Botanical Garden appears to imply.

I think that we may now safely outline the methods of formation of species somewhat as follows: Through causes which are not yet at all well known, but by means of which agencies external to the germ-cells certainly may have a part, the offspring of a plant grown from seed differ more or less from the parent (variation). The thus modified offspring, subjected to natural selection, ultimately perish if they are unadapted, but survive if they are adapted to their surroundings. Repetitions of this process finally bring the descendants of plants to differ materially from their ancestors (evolution). The end of the process seems to be the development of organisms which are little or not at all subject to variation (monotypic genera). All genera of plants containing a large number of species are evidently subject to continued variation and their species and races almost defy classification. Just what part the phenomena of hybridism take in the final result is not clear, but it may be pointed out that they are evidently unnecessary, because great groups, whole orders, in fact, of the fungi, are devoid of sexuality, and hybridism is therefore impossible among them; yet they are subject to variation like other plants and are quite as difficult to classify.

Observations on insectivorous plants occupied Darwin at intervals from 1860 until the publication of his volume on that subject in 1875. He commenced with the round-leaved sundew (*Drosera rotundifolia*) while staying at Ashdown Forest, and was soon intensely interested in the exquisite sensitiveness of the leaf-glands to nitrogenous substances. His studies were continued over most of the plants of the sundew family, and to others known to entrap insects or other small animals. He discovered that the leaves of *Drosera* and of *Dionœa* secreted a ferment when supplied with various kinds of nitrogenous food and he closely observed the movements of their glands and tentacles and recorded them in detail. Experiments were also made on these plants with a great variety of non-nitrogenous substances. Darwin pointed out the remarkable parallelism between the digestive powers of the secretions of the Droseraceæ and those of the gastric juices of animals. The sacs of the aquatic bladder-worts (*Utricularia*) and the leaves of butter-worts (*Pinguicula*) were also closely studied. His book is replete with records of careful observations and ingenious deductions. *Nepenthes* had already been shown by Dr. Hooker to secrete digestive fluids in its pitcher-like leaves, and *Sarracenia* was suspected of similar activity by Darwin and by others, although he did not regard this as proved.

As early as 1838 or 1839 Darwin was attracted to observe the processes of pollination and noticed the dimorphic flowers of *Linum flavum*. He had concluded at that time that cross-fertilization was potent in holding species stable and constant. He obtained a great deal of information on this topic in 1841 by reading Sprengle's "Entdeckte Geheimniss der Natur," which stimulated him to continued investigations during summers and he became especially interested in the methods of pollination of the wild orchids growing about his home. This study of pollination of orchids resulted in the publication, in 1862, of his book on that subject, and in it his detailed observations are recorded. Some of his closest observational work was done on this subject of cross-pollination, and he examined a great many species and grew thousands of plants from seed, reaching the broad generalization that cross-fertilization is beneficial to a species and self-fertilization is injurious. The phenomena do not now, however, appear to have as important a relation to evolution as they were formerly supposed to have, and Darwin later expressed regret that he had not given more attention to the processes of self-fertilization.

His interest in showing that cross-fertilization was beneficial led him to closely investigate the various structural features of flowers which necessitate this process to a greater or less degree, such as diœcism, monœcism, polygamy and heterostyly; his observations and speculations are presented in the volume entitled "Different Forms of Flowers and Plants of the Same Species," published in 1877. He records that making out the meaning of heterostyled flowers gave him very great pleasure. A chapter of the book is devoted to cleistogamic flowers, which are necessarily self-fertilized and produce seed abundantly. This work is largely a revision and rearrangement of several papers previously published in the *Journal of the Linnæan Society.*

"The Variation of Animals and Plants under Domestication," Darwin's largest work, appeared in 1868, published in two volumes. As bearing on this topic he had studied, among plants for many years, the cereal grains, garden vegetables, edible fruits, ornamental trees and ornamental flowers. In the preface he again discusses natural selection and defines it as "This preservation, during the battle for life of varieties which possess any advantage in structure, constitution or instinct," noting that Herbert Spencer had well termed the same process "The Survival of the Fittest." But the bulk of the work is given to the consideration of selection by man—artificial selection, by which races useful to us, economically or esthetically, have been preserved and modified, some of them having originated in very remote times and been taken advantage of by uncivilized man. A chapter is devoted to the phenomena of bud-variation, in which many cases of branches of plants different in one respect or another from other branches on the same plant are described in detail. Many of these have been taken advantage of by horticulturists for the propagation of valuable races. He did not reach any definite conclusion as to the cause of these interesting occurrences; but recently acquired knowledge of mutation seems to indicate that they are of that category, differing from seminal mutations in that a cell in the axil of a leaf is affected rather than a germ-cell. In these volumes we find Darwin's most detailed discussion of heredity of variability and of hybridism and the last chapter outlines his provisional hypothesis of Pangenesis, an ingenious supposition, applying to living matter the general features of the atomic theory, with an additional inherent power of reproduction of the atoms or "gemmules" as he termed the hypothetical ultimate particles.

The movements of plants and of their various organs were also studied by Darwin for many years. His first essay on this topic appeared in 1865 and ten years later he revised and enlarged it as a book under the title "The Movements and Habits of Climbing Plants," using, as always, not only his own detailed and extensive observations, but also the published writings of other botanists, among them the paper on tendrils by Hugo de Vries, who was subsequently destined to throw such a flood of light on the phenomena of variation. Darwin grouped climbing plants into twiners, leaf-climbers, tendril-bearers, hook-climbers and root-climbers. He maintained that the climbing habit has been developed to enable vines to reach the light and free air; tropical forests show conclusively that this is the case. He showed that circumnutation, the bending of growing tips successively to all points of the compass, is a general phenomenon among flowering plants, and he thought it of high importance to them. The sensitiveness of tendrils to external influences interested him deeply and he made many original experiments upon them. Following the subject much further, he published in 1880 the work entitled "The Power of Movement in Plants," a treatise abounding in records of original observations on seedlings and parts of mature plants, including further studies of circumnutation, of the sensitiveness of plants to light and to other forces, and of the phenomena of geotropism and apogeotropism, which he regarded as modified phenomena of circumnutation.

The value of the impulse given by Darwin to botanical investigation in all its branches is beyond estimation; his power of exact observation and record has seldom been equaled and certainly never excelled; his deductions were highly philosophical and most of them have stood the test of thirty years' inquiry and criticism; he was searching for truth and his absolute honesty in research is plainly evidenced by his repeated criticism of his own conclusions.

The immense number of plant species which had been described and named, and the lack of any complete index to them led Darwin to provide in his will for complete enumeration of the names of published species of flowering plants. This great work was prepared at the library of the Royal Gardens, Kew, England, and published in 1895 in four large quarto volumes, to which several supplements have since been added. This "Index Kewensis" is a great boon to all investigators, and is quite indispensable to those who have to take plant names into consideration.

DARWIN AND ZOOLOGY[1]

By Dr. HERMON C. BUMPUS
AMERICAN MUSEUM OF NATURAL HISTORY

THIS is an assembly composed substantially of members and friends of the New York Academy of Sciences, united to do homage to one whose genius has been long felt in our meetings, and whose influence is now recognized in every field of intellectual endeavor. The example of Darwin's precision in observing, of his wisdom in interpreting, and of his truthfulness in recording the phenomena of nature, has transformed zoology—the subject assigned to me—from prosaic description to acute speculation, from a merely interesting study to an aggressive science.

This change has taken place in an incredibly short space of time, and it may be worth while, on an occasion such as this, to examine the condition of scientific academies and similar organizations in America at the time of the publication of the "Origin of Species," to note the first center of appreciative acceptance and to trace the spread of the belief in Darwinism as it betrayed itself in the publications of the time.

Fifty years ago there were in America five leading centers of organized scientific activity.

In Philadelphia were the American Philosopical Society, founded by Franklin, and then well along in its second century of "promoting useful knowledge," and the Academy of Natural Sciences, approaching its semi-centennial.

In Boston were the adolescent Boston Society of Natural History, approaching its thirtieth birthday, and the mature American Academy of Arts and Sciences, founded in 1780.

In New Haven was the Connecticut Academy, founded in 1786.

In Washington, although the National Institution for the Promotion of Science (founded in 1840) and the Smithsonian Institution had been publishing for eleven years, men of science apparently did not unite in an academic way until the Philosophical Society of Washington was organized in 1871. Even the National Academy was not incorporated until 1863, four years after the announcement of the "Origin of Species."

In New York, this academy (then called the Lyceum of Natural History) was meeting at Fourteenth Street, at a point now occupied by the headquarters of Tammany Hall. Of those then attending its meetings, but one now remains.

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[1] An address given at the American Museum of Natural History on February 12.

The dominant mind at Philadelphia was that of Leidy, thirty-six years of age. Cope was a boy of nineteen. In Washington, were Joseph Henry, sixty-two; Bache, sixty-three; Baird, thirty-six, and others attached to the Smithsonian Institution, and the great government surveys. Baird was often a contributor to the publications of the New York Lyceum of Natural History.

In New York was Torrey, a man of sixty-three, and among others two young men, Theodore Nicholas Gill—the senior member of this academy—and Daniel Giraud Elliot, now honoring this museum with his presence—both born in New York, and both in their early twenties. Not only have these two—early identified with the scientific publications of this academy—witnessed the change that has taken place during the past fifty years, but their long series of contributions to science admirably illustrate the strange power that has been exerted upon zoological work in general, and descriptive zoology in particular, by him who came into being one hundred years ago.

In New Haven were James Dwight Dana, forty-six; Daniel C. Gilman, twenty-eight, and the Sillimans.

In Boston, were Agassiz, adored by the people—preeminent among teachers—the studious lovable Gray, at one time (1836) librarian of this academy, and Jeffries Wyman. Both Agassiz and Gray were about the age of Darwin. Jeffries Wyman was a few years their junior; of him Lowell has written:

He widened knowledge and escaped the praise
. . . .
He toiled for science, not to draw men's gaze.

Under the influence of these, Agassiz, Gray, Jeffries Wyman, there gathered at Cambridge, at about this time, what we should now informally and affectionately call "a bunch of boys." Shaler, eighteen; Verrill (who has come down from New Haven to be with us this afternoon) and Packard, twenty; Morse, Hyatt and Allen—our Dr. Allen—twenty-one; Scudder, twenty-two.

Of the five centers of scientific activity, youth was certainly the characteristic of the school at Boston. It is therefore safe to predict that the germ of the new truth in biological science would find a more favorable medium in Boston than here in New York or farther south.

The infection was immediate, indeed "*pre*-immediate." The period of incubation extended over about ten years, ending in an acute epidemic from 1871–1876, which affected lyceums, associations and academies indiscriminately. Convalescence than began, since which the American body-scientific has enjoyed good health and has shown many periods of remarkable growth.

The "Origin of Species" was published in London late in November, 1859. The following month, Asa Gray, long intimately acquainted with Darwin, and anxious that Americans should see promptly the significance of the new theory, wrote for *Silliman's Journal* a review of the book, before a single copy of the "Origin" had reached this country. He predicted that the work would produce great discussion—it did. A copy arrived, it was carefully reviewed, but before the review could be gotten through the press, a second edition was announced, and within three months two American editions were advertised.

Gray gave his first review in December. In January, Professors Agassiz, Parsons and Rogers are recorded as having discussed the "Origin and Distribution of Species" at a meeting of the American Academy of Arts and Sciences on Beacon Street. Gray was present. In February Agassiz began his open opposition to the theory of Darwin, stating at the Boston Society of Natural History that, while Darwin was one of the best naturalists in England, his great knowledge and experience had been brought to the support of an ingenious but fanciful theory.

In March Agassiz continued to oppose Darwin, and in April Gray and Parsons made their reply. In May they were at it again. Then followed the admirable essay of Parsons, Professor of Law at Harvard, and the unfortunate advance sheets of the third volume of Agassiz's "Contributions." Then came Gray's *Atlantic Monthly* articles, and thus ended the first year.

Among the records of the learned societies of New York, Philadelphia and Washington, I can find nothing to indicate that there was any particular interest in the disturbances that were going on in and about Boston. Professor Dana, easily the dominant figure in science at New Haven, was in poor health and out of the country, but it was generally considered that his intensely idealistic views would probably have prevented him from accepting a theory that was felt by many to be grossly materialistic. The infection therefore was local and remained local about Boston for a full decade.

In 1863 Jeffries Wyman, in his review of Owen's monograph on the "Aye-aye" gave inference of his adherence to the theories of Darwin, and indicated the impossibility of there being any neutral ground.

In 1864 Agassiz doubtless discussed the matter before the National Academy in a paper on the "Individuality of Animals." A copy of the paper I have been unable to find.

In 1865 Morse came to New York, from Salem, to be the guest of this academy, but the formal paper that he presented did not contain even a remote allusion to the discussions that were going on in what was then considered America's educational center.

In 1867 Hyatt's paper on "Parallelism" appeared. This I believe to be the first distinctly evolutionary contribution from the zoological side. In this year, 1867, Professor Newberry, later and for twenty-three years the president of this academy, delivered his address at the Burlington meeting of the American Association for the Advancement of Science, betraying in this a singular nobleness of character toward those to whose advanced views he felt that the scientific world could not entirely subscribe, and admirably illustrating what he interpreted to be the prevailing opinion, as shown by the following quotation:

> Although this Darwinian hypothesis is looked upon by many as striking at the root of all vital faith, and is the *bête noire* of all those good men who deplore and condemn the materialistic tendency of modern science, still the purity of life of the author of the "Origin of Species," his enthusiastic devotion to the study of truth, the industry and acumen which have marked his researches, the candor and caution with which his suggestions have been made, all combine to render the obloquy and scorn with which they have been received in many quarters, peculiarly unjust and in bad taste.

This was also the first year of the *American Naturalist,* edited by those four pupils of Agassiz—Packard, Morse, Hyatt and Putnam—of whom two are still spared. The introduction of the charming first volume of this characteristic American publication is sufficient proof that at the time of its issue even the younger men felt that there were two distinct schools of thought relative to the "Origin of Species"—Those who are familiar with this introduction will remember that it is illuminated with one of Morse's inimitable sketches, a snail peering through a binocular microscope, symbolical, doubtless, of the slowness of perception of those who clung to this archaic instrument and possibly also of those who cling to archaic ideas.

The following year, 1868, the Academy of Natural Sciences of Philadelphia, which in 1860 had elected Darwin to membership, published the first important direct contribution to the subject of evolution made by one not directly under the influence of the Boston academies. This contribution, "On the Origin of Genera," was made by Cope, who for several years had been submitting papers to the academy of a descriptive and semi-speculative character, and largely dealing with the classification of reptiles. I believe that I am perfectly safe in saying that no academy in America has ever published a paper that reflects more to its credit than this extraordinary essay of Cope. It is apologetically issued as a fragment, but in it there are shown an intimate acquaintance with anatomical detail that is almost supernatural, an independence of thought that is extraordinary, a power of analysis that stuns the reader, an estimate of the weak and the strong points of the Darwinism theory that is masterly, an agility of logic that marks its author as a dangerous antagonist, an energy to reach the truth, and an impetuosity to convince others of truth, that is prophetic, indeed, that is completely demonstrative of pent-up mental power, which must have been most disturbing to those of his academy who had nestled down into positions of comfortable intellectuality.

We now enter upon the five years of acute activity.

On December 15, 1871, Cope attended a meeting of the American Philosophical Society, and presented his paper on "The Method of Creation of Organic Forms." In a fortnight a reply was given, which began with a quotation from Job: "I am a brother to dragons and a companion to owls," and continued for several pages in attempted explanation and demonstration of the falsity of Darwin's theories, and ended with the author's conviction that the only good that can come from these theories is the fact that they must bring about their own defeat.

Cope replied immediately and was then replied to, and so on. But why follow the discussion?

The spell was being felt even farther south. Within two months of the date of its founding, the Philosophical Society of Washington listened to a paper by Professor Gill, in which it was stated that if the doctrine of evolution was accepted at all, it must involve man.

This was also the date of Dr. Allen's paper on the "Geographical Variation of North American Birds," a philosophical as well as a descriptive article, an important contribution to the then scant literature of distribution, a paper which established a distinct method of zoological research that has reflected the highest credit on its author and on the institutions with which he has been connected.

It was also in this year that Morse published his paper on "Adaptive Coloration."

In January, 1872, the New York Academy made its first direct contribution to the subject of evolution by publishing a brief paper on the "Carpus and Tarsus of Birds." I hope that Professor Morse, now forty-five years a member of this academy, is present at this gathering, for the fifty years that have passed since the appearance of the "Origin of Species" exactly synchronize with the period of his devotion to the principles enunciated therein.

If, among the volumes of this academy from 1859–1876, one binding shows more signs of use than the others, take down the book, and you will find that it opens to this article by Professor Morse: a contribution to zoology, to comparative anatomy, to embryology, and to the theory of evolution. It is a refreshing spot, but somewhat out of place in an arid expanse of descriptions of new species and revised classifications.

Another paper issued by the academy in 1872, and characteristic of the new thought of the time, was by Benj. M. Martin on the "Unity of the General Forces of Nature," but this was physical rather than biological.

If one were forced to accept the presidential addresses of the American Association for the Advancement of Science as indicative of the advancement of science in American associations, the address of 1873, delivered by one who said he thought that natural selection had died with Lamarck, would sadly mislead. He writes:

> In Darwin we have one of those philosophers whose great knowledge of animal and vegetable life is transcended only by his imagination. In fact, he is to be regarded more as a metaphysician with a highly-wrought imagination than as a scientist.

But this is only the beginning of the gloom that anticipated the dawn.

Although in 1874 Dr. Elsberg, in a "Contribution to the Doctrine of Evolution," addressed this academy (and also the American Association for the Advancement of Science), in favor of the principles of Darwin, although Cope continued to sustain his earlier contentions, and general workers were beginning to make original observations in favor of the principles of organic descent, the reviewers of the deliberations of scientific gatherings give little promise of anything like a general acceptance of the beliefs in which we are interested.

In 1875, the retiring president of the American Association said:

> I fear that the unhappy spirit of contention still survives, and that there are a few who fight for victory rather than for the truth.

One of the vice-presidents at this meeting declined to "enter on the vast field of discussion . . . opened up by Darwin and others," and resolved to avoid the use of the word "evolution," "as this has recently been employed in so many senses as to have become nearly useless for any scientific purpose."

Thus closed five years of struggle.

The year 1876, the centennial of political independence in America, marked also the dawn of intellectual independence and scientific freedom. It was the year of Brooks's first Salpa paper, and of his paper on pangenesis. Cope explicitly stated that the law of natural selection was now generally accepted, and the then librarian of this academy, Louis Elsberg, submitted his paper on the plastidule hypothesis, as nonchalantly as though he were discussing a lingual ribbon.

It was under these really blessed conditions that the American Association met in Buffalo and listened to a vice-presidential address fully worthy the title of the organization. Edward S. Morse had demonstrated his ability as an investigator in his paper of 1872, already mentioned, but the simple, straightforward, patient and kindly manner in which he addressed his audience in 1876, the thoroughness with which he scanned the work of others, the fairness with which he acknowledged the value of their results, and his concluding passages, in which he indicated the important bearing that the theories of descent had upon the social problems of the day, render his address a fit conclusion of a distinct epoch in the history of American science.

Since 1876, practically every zoological worker has sought to make some contribution that might strengthen his faith in a rational evolution of organic life and activities. It may be that such contributions will prove insufficient. It may be that Darwinism as a *thing* will ultimately fail of proof, but to those in the future who may inquire for the reason for these exercises and for the erection of this monument, *Darwinism as a method* will ever be a sufficient reply.

FOR DARWIN[1]

By Professor T. H. MORGAN
COLUMBIA UNIVERSITY

WE have come together to-day to consider Darwin's influence on zoology. It is a hazardous task to pretend to estimate the influence of any event on the course of history so long as we can not know what the outcome had been otherwise. But to this at least we can testify, that it is the general belief of zoologists to-day that Darwin's influence in bringing about the acceptance of the theory of evolution marks a turning point in the history of their science, and I shall attempt to justify this opinion by pointing out the condition of zoology before Darwin and its subsequent course of development after 1859.

To the zoologist Darwin was above all else a zoologist. It is true he interested himself greatly in geology, but he does not stand as a leader of that science; he carried out many experiments with plants and wrote some important botanical books, and here the zoologist will yield second place to his brother, the botanist. Darwin wrote on the "Descent of Man," he studied the expression of the emotions and carried out physiological work along several lines, yet I should not rank him preeminently an anthropologist, a psychologist or a physiologist any more than a paleontologist or a botanist.

In the mind of the general public Darwinism stands to-day for evolution. The establishment of the theory of evolution is generally accepted as Darwin's chief contribution to human thought, and while Darwin did not originate this idea that forms the framework of our modern thinking, yet by general accord its acceptance is attributable, and justly so, to Darwin.

To the zoologist Darwinism means more especially evolution accounted for by the theory of natural selection, yet also many other things, to which I shall refer in the proper place.

But I shall attempt this afternoon, before all else, to convince you that the loyalty that every man of science feels towards Darwin is something greater than any special theory. I shall call it the spirit of Darwinism, the point of view, the method, the procedure, of Darwin.

In order that we may form some idea of Darwin's influence on zoology, let us examine the condition of that science prior to 1859 to

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[1] A lecture on "Darwin's Influence on Zoology," delivered at Columbia University, February 26, 1909.

see what influence zoology had on Darwin and his contemporaries. I shall not try your patience by attempting to review the history of the subject, but it would not belittle the greatness of Darwin's achievement one whit to find that brilliant discoveries had been made before his time, the theory of evolution plainly enunciated, the doctrine of spontaneous generation disproved; comparative anatomy widely studied; the important functions of the body elucidated, the foundations of the science of embryology laid, and the principles of pedigree breeding followed.

In the eighteenth century, when the study of different kinds of animals inhabiting sea and land attracted the attention of zoologists, great classifications were invented. Two main facts emerged. On the assumption of fixity of type, a classification of the different forms of animals and plants became possible. But on the other hand the more extensive the material to be classified, the more difficult it became to make such systems, for the fixity of type was often lost in apparent transitions to other types. Counter claims arose as to the superiority of one system over another, and the question of an artificial system versus a natural one was widely debated. Now, an artificial system, like the arrangement of the words in a dictionary, is obviously only a matter of convenience, but it became a question of deep philosophical importance to decide what was meant by a natural classification. To us at the present time a natural classification implies a relation due to descent; it is neither more nor less than the natural relation of a man to his ancestors. But it were a fatal mistake to read our meaning backwards to the time before Darwin.

To the great Cuvier a natural system meant an assemblage of groups having a common plan of structure, and he was enraged by Geoffroy St. Hilaire's attempt to put all animals from the bottom to the top in a straight line. A common plan of structure might only mean that idea which best expressed the outcome of a wide study of structure; but to those who tried to peer behind the scenes it meant not seldom to fathom the creation of the world; and it required no vivid imagination to add that it gives an insight into the plan by which the world was created.

A historian of the times wrote:

> Yet in fact the assumption of an end or purpose in the structure of organized beings appears to be an intellectual habit, which no efforts can cast off. It has prevailed from the earliest to the latest ages of zoological research, appears to be fastened upon us alike by our ignorance and our knowledge . . . and the doctrine of unity of plan of all animals, and the other principles associated with this doctrine, so far as they exclude the conviction of an intelligible scheme and a discernible end, in the organization of animals, appear to be utterly erroneous.

Contrast, in passing, this pious conviction with Geoffroy's modest lines:

> I ascribe no intention to God, for I mistrust the feeble powers of my reason. I observe facts merely and go on. I can not make nature an intelligent being who does nothing in vain, who acts by the shortest mode, who does all for the best.

Thus arose in the eighteenth and nineteenth centuries the dogma of the fixity of species—a dogma based, it is true, on a direct appeal to fact as well as to conscience. But this dogma contained the germ of its own undoing, in so far as it appealed for its support to observations that every man might make for himself. Yet so influential were its advocates, so convinced of its truth, that more than one assault was made before it crumbled away.

It is no small pleasure to repeat to-day the names of those bold and original thinkers, who braved the displeasure of their compatriots and the contempt of their times, who brought forward evidence and argument to disprove the teaching of the schools. Their work, it is true, failed in the sense that it received no sufficient meed of praise or word of commendation, but who will deny that a seed was sown that in time bore fruit? Foremost, I think, ranks the great Lamarck, the centenary of whose "Philosophie Zoologique" is celebrated this year in France—a bold spirit, whose ideas, based on a wide familiarity with facts, live and bear fruit to-day. Geoffroy St. Hilaire, advanced thinker and philosopher of nature, opponent of the great anatomist Cuvier, brought the problem of evolution to the bar of judgment, losing the decision, it is true, but his ideas a later generation hold in high esteem. Erasmus Darwin, grandfather of our Darwin, author of "The Zoonomia," celebrated in verse "The Botanic Garden" and the "Loves of the Plants," and even before Lamarck, advocated the principle of evolution and the thory of inheritance of acquired characters. Herbert Spencer, adopting the idea of evolution, laid thereon the elaborate superstructure of his philosophy. Robert Chambers, too, kept alive the central idea of change in the organic world in his "Vestiges of Creation." Others there were, besides, in different lands, but these especially were nearer to Darwin and his times.

We come now to the years between 1837 and 1844, when Darwin was making his memorable notes on the relation between varieties and species. Reading through his letters of this period one is surprised to find how little he was impressed by the history of zoology and the influences of his own time, and how much he based his conclusions on the results of his own close observations, his accumulation of data, and careful consideration of facts. In regard to Lamarck, Darwin states in his autobiography, that in 1825 when he was at Edinburgh University, Dr. Grant "burst forth in high admiration of Lamarck and his views on evolution. I listened in silent astonishment, and as far as I can judge, without any effect on my mind."

In later years, after reading Lamarck, Darwin wrote Lyell, in 1859:

> You often allude to Lamarck's work; I do not know what you think about it, but it appeared to me extremely poor; I got not one fact or idea from it.

Writing to Lyell in 1863, he says:

> You refer repeatedly to my view as a modification of Lamarck's doctrine of development and progress. . . . Plato, Buffon, my grandfather before Lamarck, and others, propounded the *obvious* views that if species were not created separately they must have come from other species, and I can see nothing else in common between the "Origin" [of Species] and Lamarck.

Darwin wrote to Hooker in 1844:

> Heaven forfend me from Lamarck's nonsense of a "tendency to progression," "adaptations from the slow willing of animals," etc. But the conclusions I am led to are not widely different from his; though the means of change are wholly so.

Darwin had read "The Zoonomia" of his grandfather prior to 1825 in which "similar views [to those of Lamarck] are mentioned but without producing any effect" on him. He continues, with his usual candor:

> Nevertheless it is probable that the hearing rather early in life such views maintained and praised may have favored my upholding them under a different form in my "Origin of Species."

It is a regrettable fact that Darwin did not appreciate Lamarck's work. The failure of Lamarck's writings to produce any apparent influence on Darwin may be attributed, I think, to the form in which Lamarck's views are presented. He uses facts as illustrations of his ideas, while with Darwin the facts are all important as furnishing the evidence on which a theory is to be established. He misunderstood Lamarck's view in regard to the inheritance of acquired characters, yet held himself the same opinion in the main as had Lamarck. The modern idea of descent, as a system of branching due to *divergence* in those species descended from the same parent species, was expounded luminously by Lamarck, yet Darwin discovered it independently for himself. He says:

> But at that time (1844) I overlooked one problem of great importance; and it is astonishing to me . . . how I could have overlooked it and its solution. This problem is the tendency in organic beings descended from the same stock to diverge greatly in character as they become modified. That they have diverged greatly is obvious from the manner in which species of all kinds can be classed under genera, genera under families, families under suborders, and so forth, and I can remember the very spot in the road where to my joy the solution occurred to me.

It is this same view that Lamarck had fully expounded thirty-five years before.

We have now arrived at the period just before the publication of Darwin's famous book. It is sometimes said that the time was ripe for the reception of the ideas formulated by Darwin—it was in the air, as we say—but if so, it must have been so attenuated as to be invisible to eyes as sharp as Huxley's and the other famous naturalists of that time. Huxley says that within the ranks of the biologists he met with but one who had a word to say for evolution. Outside these ranks the only person known to him "whose knowledge and capacity compelled respect" and who advocated evolution was Herbert Spencer. "Many and prolonged were the battles they fought" on this topic, but Huxley maintained his agnostic position. He states:

> I took my stand upon two grounds; firstly that up to that time the evidence in favor of transmutation was wholly insufficient; and secondly that no suggestion respecting the causes of the transmutation assumed which had been made was in any way adequate to explain the phenomena. Looking back at the state of knowledge at that time I really do not see that any other conclusion was justified.

This frank statement of Huxley not only gives us an insight into the position of one of the most progressive zoologists of that time, but what is of more importance it implies also *why* the "Origin of Species" convinced him of the doctrine of evolution.

We have now sufficiently traced the possible influences of the times on Darwin. Before we proceed to study the influence of Darwin on his time, let us for a moment pause to consider what influence Darwin's own surroundings had in shaping his views. His voyage in the *Beagle* had brought him in contact with the question of geographical distribution. He read Malthus in 1838 and this gave him his first idea of the survival of the fittest; and, as his son and biographer states, this date marks "the turning point in the formation of his theory," so that by 1844 he formulated "a surprisingly complete presentation of the argument afterwards familiar to us in the 'Origin of Species.'" His extensive study of variation under domestication furnished him with the experimental evidence that went so far towards making his study of variation of far-reaching and profound importance. Indeed, in this one essential respect, Darwin was far ahead of all of his contemporaries, and, if you will pardon the anachronism, far ahead of his successors. It is only in recent years that zoologists and botanists have begun once more to work the rich mine of materials at their very doors. The paper of Wallace on "Natural Selection" in 1858, the reception to the "Origin of Species" in 1859, the storm of disapproval it met on the one hand, the staunch and able friends it made on the other, need only be recalled in passing.

We come now to the influence that Darwin's work has had on modern zoology. That influence is due not alone to the "Origin of Species" that gave to the world an abstract only of his views, but equally to his other works, especially, I think, the "Variation of Animals and Plants under Domestication," and the "Descent of Man." After Darwin and largely as an outgrowth of the wide interest his views aroused in all branches of zoology we find activity going on in many lines of work. One group of workers, the systematists, have kept nearer, I think, to the older traditions. They have been concerned with three of the most important matters that have a direct influence on the "Origin of Species"—the intensive study of species and varieties, the geographical and geological distribution of animals, and the influence of the environment in modifying species. Their results have supplied the most extensive contributions, perhaps, that have been made to the theory of species-formation and transmutation. They seem to me, however, to have paid less attention to another, equally important, field, that of the adaptation of animals to their environment, and the causes that have been effective in bringing about this adaptation. To physiology we look in vain for an answer to this question, that is perhaps a physiological problem, for while physiology has advanced to a wonderful degree our knowledge of the complicated adjustments within the body, the origin in time of these adjustments and their relation to the outer world has excited less interest.

The morphologists, or philosophical anatomists, form the second great group of students whose activity is a direct outgrowth of Darwinism. The determination of the relationships of the great classes of animals on the principle of descent has occupied much of their time. Two other important fields of labor have also fallen to their share. The study of development or embryology has been almost exclusively pursued by morphologists, inspired in large part by the theory of recapitulation.

The older form of the doctrine, that in the development of the individual the past history of the race is repeated, has been revived—a doctrine much in vogue in the early part of the last century, which has continued to have its followers despite the different interpretation that von Baer gave to the same facts. Whatever interpretation we choose at the present time, the presence of structures like gill-slits in the human embryo, directly comparable to those in the fish, has had an important influence in disentangling the relationship of living animals to their remote ancestors.

The morphologist has also undertaken the study of heredity, and the relation of heredity to the germ-cells that are the links in the chain of organic life. Few other studies have advanced in recent years at a more rapid pace and few have yielded facts of greater significance, for here lies the key to the origin and nature of variations.

Systematists and morphologists alike have been evolutionists, but it is a curious fact of zoological history that until very recently there has been no body of students whose interests have been directed *primarily* towards the problems of evolution. This is due, I think, to a general feeling that the data for evolution are rather the by-products of the zoologist's work-shop, than products directly manufactured by him, despite the splendid example of Darwin to the contrary. Is it not strange, therefore, with all the real interest in the theory of evolution, that so few of the immediate followers of Darwin devoted themselves exclusively to a study of that process? As I have said, the systematists have been accumulating a vast amount of valuable material, but their chief interest has, on the whole, been in its classification, only secondarily in its bearing on evolution. The morphologist has been busy in *applying* the theory of evolution to the explanation of group relationships. The paleontologist has perhaps been more directly concerned with the evolution question than has any other worker.

There is a school that calls itself Lamarckian or Neo-Lamarckian which as far as its name goes should include the followers of Lamarck rather than of Darwin. Yet with few exceptions the Neo-Lamarckians derive their inspiration, I think, directly from Darwin. Darwin held that characters acquired during the life-time of the individual may be transmitted to the offspring. He abhorred what he supposed to be Lamarck's rubbish, that an animal acquired a new part by willing it. We have seen that this is a travesty on Lamarck's real teaching, and that on the whole Darwin's view of acquired characters is almost Lamarck's. Yet the modern Lamarckians get their doctrine direct from Darwin rather than from Lamarck, who propounded it fifty years earlier, as had Erasmus Darwin, still earlier.

I have laid emphasis on the relation of Lamarckism to Darwinism in order to draw attention to the problem of adaptation. The Neo-Lamarckians have kept this all-important question in the foreground, while others have taken adaptation too much for granted in their attempts to explain the origin of species; for species, in a technical sense, may have little to do with the problem of adaptation. The life of an animal is intimately dependent on its adaptative characters, but its "specific characters" may be largely unimportant for its existence.

Systematists and morphologists include broadly the followers of Darwin during the thirty years after the publication of the "Origin of Species." They have advanced to a high degree the principles of their science, and the modern aspect of zoology is largely the outcome of their varied and far-reaching labors.

There is a small group of writers scattered amongst these larger groups that are ranked or rank themselves Neo-Darwinians. I must pause a moment to pay them my tardy respects. They have set themselves up to be the true Darwinians. They seem less concerned with the advancement of the study of evolution than with expounding Darwinism as dogma. Their credulity is more remarkable than their judgment. To *imagine* a use for an organ is for them equivalent to *explaining* its origin by natural selection without further inquiry. Any examination, in fact, into the nature of variation, they appear to regard as superfluous, although harmless, but it is heresy to study critically the working out of the theory of natural selection. Such has ever been the procedure of the infertile followers of great leaders. In the present instance the result is the more deplorable, since Darwin's own independence of the traditions of all schools, his careful study of facts, his emancipation from prejudice, are his lasting virtues. The Neo-Darwinian, worshipping the letter of the law, forgets its import. Let us salute, and pass.

And now we come to the last twenty years of zoology as influenced by Darwin. This, I believe, is the brightest chapter of Darwinism, for the spirit of Darwin is once more abroad.

Foremost amongst the many debts that modern zoology owes to Darwin is this: he pointed out that in order to understand how evolution takes place, we must study the variations of animals and plants, for here is the material on which rests any solid superstructure. To my mind, the appreciation of this maxim and its application is the distinguishing feature of Darwin's work. Before his time the theory of evolution remained but a general idea, though one of profound significance. After Darwin, the theory of evolution rested its claims for recognition on a definite body of information relating to variations and their inheritance. It is these data that first convinced his greatest contemporaries of the reality of evolution, and finally convinced also the rank and file of thinking men. So extensive were the facts of variation accumulated by Darwin, so penetrating was his analysis of these facts, so keen was his insight, and so wise his judgment as to their meaning, that for thirty years afterwards little of importance in this direction was added. In their amazement at Darwin's accomplishment zoologists forgot that he had opened the door leading into an unexplored territory. During the last twenty years the march forward has once more begun and the reward has been immediate.

Let us tarry therefore a little in these rich and pleasant fields of discovery and examine in some detail what is being done. The study of variation has been actively pursued in three main directions. The biometricians have applied exact measurements to variation; the ecologists have studied the complex influences of the environment; the experimentalist has put to the test the supposed factors of change. Each of these methods has brought out results of significance.

A careful study of variations within each species has shown that taken as a group many variations conform to the law of probability. Popularly expressed, this means that chance determines variations, or, put more exactly, variations taken as a group and measured, give the same mathematical results that follow when any set of objects become arranged according to the laws of probability. There was a time when chance meant lack of conformity to law. Such a popular interpretation has no scientific standing. The great law of causation is not abrogated, but the outcome is only the result of a large number of small influences whose effects depend on the nature of the material and on the nature of the conditions. It is so important that this fact be clearly understood that I may be pardoned if I call to mind some familiar illustrations. No two leaves on a tree are identical, yet if many are measured, they give the curve of probability. Men are of different heights, yet they range about a mode. Color appears in various shades, yet if standardized, it is found to follow the same laws of chance variation.

What value have these facts for the theory of evolution? If in every generation we find that the same kinds of individuals recur, the results mean stability, not progress. That this state of affairs actually exists in many species living under the same environment during successive generations there can be little doubt. But change the environment and the results also change. Another factor comes to light that is independent of outside conditions. It is what has been called preferential mating. If within a group the males and females of certain kinds tend more often to pair with each other, the collective group becomes modified in one or more directions. In man this factor assumes a special importance, for, as Pearson has shown, there is measurable evidence that such mating occurs.

It has often been urged, and I think with much justification, that the selection of individual, or fluctuating variations could never produce anything new, since they never transgress the limits of their species, even after the most rigorous selection—at least the best evidence that we have at present *seems* to point in this direction. But a new situation has arisen. There are variations within the limits of Linnean species that are definite and inherited, and there is more than a suspicion that by their presence the possibility is assured of further definite variation in the same direction which may further and further transcend the limits of the first steps. If this point can be established beyond dispute, we shall have met one of the most serious criticisms of the theory of natural selection.

It is not without interest to note in this connection that Darwin often assumed that *fluctuating variations* are transmitted to the offspring. The idea that they are not was a later development—the result, it is true, of a better knowledge of the law of fortuitous effects, or of probability. But we have discovered the additional fact that *some small* variations are inherited. Let us call these *definite variations,* and if these be the material with which evolution is concerned, Darwin's assumption in regard to the nature of variation will be, in part, justified.

These small, definite variations appear to be closely allied to those larger, more visible definite variations that we now call mutations.

We owe our modern ideas of such variations mainly to de Vries and to those who have followed in his footsteps. Such sudden changes have been long known and were spoken of by Darwin as saltations—or sports. Darwin knew of cases like the ancon ram, from which a race of short-legged sheep was produced. He knew that totally black or melanistic mutations and albinos arise in many groups suddenly, and transmit their characters. A black-shouldered or japanned peacock has appeared more than once and perpetuated itself without selection. It would be out of place to-day to discuss this absorbing problem. That extreme mutations may at times have been an element of progress in nature few will deny, especially if we exclude such monstrous forms as those the breeder has used in building up domesticated races of animals.

It is not, however, to these extreme examples of definite variations that I wish especially to draw your attention, but to that group of smaller variations of a similar nature that may at their first appearance fall within the limits of ordinary variability. I now ask you, therefore, to follow me in an attempt to apply this latest discovery to the theory of evolution.

If we trace the ancestors of any living animal—man, for example—we discover that his ancestry goes back not as a single line, nor as a converging system of lines, but as a vast branching network. Each man has had 2 parents, 4 grandparents, 8 great-grandparents, 16 in the fourth generation, 32 in the fifth, 64 in the sixth, 128 in the seventh, 256 in the eighth, 512 in the ninth, 1,024 in the tenth. A few generations further removed we should expect to find that the majority of all the individuals of the species had poured their blood, as we say, into each individual of the future generations. Each of us is the descendant of a large population. The statement is not strictly true, for some lines die out, many lines cross, and caste has narrowed the field, but the statement suffices to show that a species moves along as a horde rather than as the offspring of a few individuals in each generation. The mass serves to keep the species afloat in times of calamity, it may have little else to do directly with its advance. Nevertheless this fundamental fact is too often overlooked in the attempt to explain the origin of new races, varieties and species from single favorable variations.

For *advance* we must look to those individuals that contribute something new to the species—it is the superman that will add something to the common level of humanity, but the rest keep the race alive until his advent and then carry his kind forward on an advancing wave.

If we could count those individuals that are the pioneers of advance, their number might be very small; in order to survive, they must graft themselves onto the stock. They are the harbingers of the better times to come—the forerunners of progress.

We touch here the crucial point of evolution in its relation to Darwin's principle of natural selection. Darwin says that he did not at first realize the overwhelming influence of the mass in its swamping effects on the individual variant. He made a very important concession to this view in the later editions of the "Origin of Species," and thought it necessary to assume that for a new form to arise it must first appear in a large number of individuals.

But to-day the situation has changed and new facts have come to light—facts that remove the enormous difficulty that Darwin met by what may seem now to have been an unnecessary concession.

An imaginary case will illustrate what I wish to say. Suppose that a species consisted in each generation of a million individuals and let us imagine that a new character—a definite variation—appears in an individual. The individual that bears it will pair with another ordinary individual and transmit its new character to all of its offspring. In order to simplify our case let us imagine that from each pair of individuals four reach maturity. The million of individuals has increased to two millions, but accidents and competition may kill off one million of these, so that the race is again reduced to its standard of one million. If, then, we suppose that two of the new kinds of individuals survive on the average, and pair at random, there will be eight in the next generation (in reality only six of the eight will show this character). If these survive they will transmit their character to twelve of their offspring. Gradually, however, step by step, the new character will be added to the whole race. Thus any new, definite character will gradually appear in all the individuals whether it is useful or not. If it is useful it may sooner implant itself on the race than if it is indifferent; for more individuals may survive that possess it, than of those without it. It will spread faster, but in any case it will come in the long run. Thus we see that it spreads, not because it is advantageous, but because it is a definite variation. Injurious characters will have greater difficulties in inflicting themselves on the race, and if distinctly injurious may never succeed.

While one character is spreading, other definite variations may also be adding themselves to the race. Those individuals that combine the greatest number of useful additions will have the best chance of survival. Slowly the race advances in the direction of the sum of its advantages and adaptation; success, not in one but in several characters, is the true criterion of survival.

To fix our attention on each single advantage and to ascribe to it alone the palm of victory gives an incomplete idea of the progress of evolution, for evolution follows the line of the greatest number of adaptations. Success in every generation cannot be traced to one variation, but to the sum of all mingled advantages.

This interpretation broadens, I think, our general conception of natural selection. We see that it is erroneous to suppose that all the individuals that bear a particular, useful trait owe this trait to their descent from one kind of individual, in the sense that this individual is the sole ancestor of all the later survivors. The first individual is not alone the ancestor of all the individuals that later bear its mark, it is only one of 999,999 ancestors that have contributed to the perpetuation of the race.

In order to simplify the case we have imagined that the new variation has appeared in a single individual. Should it appear in more than one, or arise again and again, its implantation would be thereby hastened, but the principle remains the same.

My contention may be summed up in a sentence. Survival-value is not the only test for the perpetuation of any one useful character; it is the sum total of useful variations that determines progress. The species moves as a group always. Evolution is not a simple but a complex problem. This is the general opinion held by most modern zoologists.

To-day there are three great rival claims that attempt to explain how evolution takes place: (1) that which adopts the theory of natural selection in one or another of its aspects; (2) that which maintains that acquired characters are inherited; (3) that which, trying to penetrate deeper into the mystery of life, ascribes to living matter a purposefulness—an almost conscious response to "the course of nature."

In a few concluding words I shall try to point out the standing of these rival claims.

Darwin himself adopted both the first and the second of these veiws. His whole philosophy stands opposed in principle to the third view. He did not hesitate at times to adopt the theory of the inheritance of acquired characters, whenever the facts seemed more in accordance with that interpretation than with that of natural selection. He strenuously objected that he had never intended to refer the entire process of evolution to natural selection, and later in life affirmed that he had perhaps laid too little stress on the influence of the environment. To-day the doctrine of inherited effects is in disgrace, largely owing to the brilliant attack of the philosopher of Freiburg. Nevertheless it has warm adherents; and not a few of the most cautious zoologists now living have expressed themselves in its favor. It has not lacked able advocates, but it has sadly lacked direct evidence to support it. I can show you an example of how it fails when put to the test. I have here a waltzing mouse that turns round in circles instead of moving forwards. This is a domesticated variety and breeds true, *i. e.*, all of its offspring are waltzers. I next show you a pair of mice that were injected with acetyl-atoxyl to cure them of sleeping sickness. They have artificially acquired the same habit as a result of the injection, and have waltzed for nearly a year. Here are their offspring that show not a trace of the trick.

Cases like these, and I could cite not a few, show how cautiously we must view the theory that such acquired characters are inherited. The experiments do not disprove the possibility, but until direct evidence is forthcoming, judgment must remain suspended.

It has seemed, therefore, to many modern zoologists that we must face the two alternatives, either natural selection or purposeful response. Natural selection has been likened in recent years to a sieve that lets the non-adapted pass through and conserves the adapted. On the sieve metaphor natural selection produces nothing—it is described as a process of destruction of the unfit. How then can natural selection the destroyer become a factor in a creative process?

I have already tried to indicate how natural selection may assume such a rôle. If definite variations appear, however small or large, that are of some benefit, they may engraft themselves in time on to the species; if other useful definite variations are also adding themselves, if their presence insures some further definite variations in the same directions, advance is certain. In other words the elimination of the unfit has not produced the fit, but it has left the conditions more favorable for further progress in the direction of fitness. This is the interpretation of Darwinism that attracts at present the serious attention of the most thoughtful and advanced students of evolution.

I hesitate to bring before you in a closing sentence or two the alternative doctrine of purposefulness—a doctrine so fraught with human and superhuman import, for of all theories of creation it undoubtedly makes the strongest emotional appeal to mankind.

We are so conversant with the fact in human affairs that whenever purpose is involved there is an intelligent agent—a mind that designs, a mind that foresees—that our thinking has become tinctured with the idea that *wherever* there is purpose there is something like mind that has anticipated it. Organic nature is full to the brim of what seems purposeful adaptation—means to ends. Two modern zoologists and a noted philosopher have nailed this banner to their mast-head.

There is one consideration above all others that warns the zoologist against speaking dogmatically about purposefulness, or its absence, in the response of living matter to its environment—his ignorance of the causes of variation. If I have implied that *all* variation is purely "accidental"; if I have led you to infer that it is entirely fortuitous, I have gone beyond the facts. We must be careful to distinguish between the individual differences that we can safely ascribe to chance, and the small definite variations that arise in the germ. The latter appear to be limited, to be in part determined by the internal nature of the parts affected, and to be constant when they have once appeared, but more than this we dare not affirm. We may believe if we like that the evidence indicates that they are not purposeful, but we can not prove this. If *they* are not purposeful then the purposefulness of the living world has no *direct* relation to the origin of useful variations. The origin of an adaptive structure and the purpose it comes to fulfill are only chance combinations. Purposefulness is a very human conception for usefulness. It is usefulness looked at backwards. Hard as it is to imagine, inconceivably hard it may appear to many, that there is no direct relation between the origin of useful variations and the ends they come to serve, yet the modern zoologist takes his stand as a man of science on this ground. He may admit in secret to his father confessor, the metaphysician, that his poor intellect staggers under such a supposition, but he bravely carries forward his work of investigation along the only lines that he has found fruitful.

In the last analysis it is a matter of expediency; or if the word jars, a matter of instinct. Why forsake the gold mine at our feet, because the transmutation of metals is a philosophic possibility?

Whether definite variations are by chance useful, or whether they are purposeful are the contrasting views of modern speculation. The philosophic zoologist of to-day has made his choice. He has chosen *undirected* variations as furnishing the materials for natural selection. It gives him a working hypothesis that calls in no unknown agencies; it accords with what he observes in nature; it promises the largest rewards. He does not deny, if he is cautious, the possibility that there may be a purposefulness in the sense that organisms may respond adaptively at times to external conditions; for the very basis of his theory rests on the assumption that such variations do occur. But he is inclined to question the assumption that adaptive variations *arise because* of their adaptiveness. In his experience he finds little evidence for this belief, and he finds much that is opposed to it. He can foresee that to admit it for that all important group of facts, where adjustments arise through the adaptation of individuals to each other—of host to parasite, of hunter to hunted—will land him in a mire of unverifiable speculation. He *fears* to enter thereby on a field of exploitation of nature that has proved itself so sterile in the past.

We have reached the end of our theme. If I have led you too far into some of the remote corners of zoological thought, I must plead that such thoughts are the legitimate outgrowth of Darwinism.

I have tried to show you the modern zoologist at work on the great theory of evolution. We stand to-day on the foundations laid fifty years ago. Darwin's method is our method, the way he pointed out we follow, not as the advocates of a dogma, not as the disciples of any particular creed, but the avowed adherents of a method of investigation whose inauguration we owe chiefly to Charles Darwin. For it is this spirit of Darwinism, not its formulæ, that we proclaim as our best heritage.

PREDARWINIAN AND POSTDARWINIAN BIOLOGY[1]

By Professor WILLIAM MORTON WHEELER
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CHARLES DARWIN undoubtedly exerted a profound and threefold influence on botany, zoology and all the kindred sciences; first, by his rehabilitation of Lamarck's theory of transformism, or evolution, as it is more generally but less aptly called; secondly, by his wonderful studies on variation; and thirdly, by the announcement of his brilliant theory of natural selection through the survival of the fittest. There is much difference of opinion as to which of these constitutes Darwin's most glorious achievement. Neodarwinists regard the promulgation of the theory of natural selection as his greatest work; experimental zoologists and botanists attribute to his studies on variation a deeper and more salutary influence on present and future investigation; while Neolamarckians insist that his labors in the cause of evolution in general, quite irrespective of whether it be conceived to result from natural selection or from other factors, is his most important contribution, not only to biological science, but to the whole body of modern thought. With this last estimate I believe that most conservative men of science will agree. Just how Darwin's work has compelled us to change our attitude so radically towards the world about us can be made clear if you will permit me very briefly to contrast the tendencies of ancient and modern science.

The unceasing flux of phenomena which is all that science can deal with has been envisaged very differently by ancient and modern observers. The Greek scientist fixed his attention on particular moments or aspects of phenomena, so that science became to him a static edifice of concepts or ideas, a hierarchy of genera and species. The scientist of to-day does not thus concentrate his attention on single moments to the exclusion or neglect of all other aspects of a phenomenon, but seeks to obtain a complete knowledge of the uniformities and constants in its occurrence and recurrence. For this reason modern science is dynamic and lays stress on laws and not on the definition and classification of concepts and ideas. These important differences between ancient and modern science have been clearly pointed out by the eminent French philosopher, Henri Bergson, in the following words:

> Ancient science believed that she understood her object when she had noted its privileged moments, whereas modern science considers it at any

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[1] Read before the Boston Society of Natural History, February 12, 1909.

> moment. The forms or ideas of a Plato or an Aristotle correspond to privileged or salient moments in the history of things—the very same moments, generally speaking, that have been fixed by language. They are supposed, like the infancy and old age of a living being, to characterize and express the quintessence of a period, all the remainder of which is filled with the transition from one state to another, and is, therefore, devoid of interest in itself. Consider, for example, the falling of a body. It was thought to be a sufficient account of the fact when it had been characterized summarily as a movement *downward*, a tendency towards a *center*, the *natural* movement of a body, which, after being separated from the earth to which it belongs, returns again to its original position. Therefore, the final or culminating point (Τέλος, ἀκμή) of a process is singled out and is erected into an essential moment, and science is satisfied with this moment, which language has seized upon for the purpose of expressing the *ensemble* of the fact. In the physics of Aristotle, the movement of a body hurled through space, or freely falling, is defined by concepts of above and below, of spontaneous and enforced displacement, of proper and improper position. But Gallilei believed that there was no essential moment, no privileged instant; in his opinion one should be able to give an account of a falling body at any moment in its course, for that is the true science of gravitation which determines the position of a body in space at any instant of time. For this purpose we, of course, need more precise symbols than those of language.[2]

To Aristotle we may also turn for a biological illustration of the differences between ancient and modern scientific observation. According to his conception, the type or privileged moment of humanity is represented by the adult male individual, with reference to whom youth and age are merely incipient and declining stages respectively, and woman is merely an abortive attempt on the part of nature to produce a man. Contrast with this our present biological conception of the sexes and the ontogeny of the human species!

It must be admitted that the tendency of modern science is in the direction of much greater refinement on the ancient method, a tendency to scrutinize more humbly and more closely, and hence, to multiply indefinitely the observed moments and aspects. I, therefore, do not use the term "ancient" in the sense of "no longer existing," since the tendency thus designated is still constantly manifested in all our ordinary thinking. To observe and retain only the privileged moments and aspects of things is for very many purposes eminently practical, but it has its disadvantages, for the more such moments of an object are accentuated or exalted, the more insignificant or debased become its other aspects. Such emphasis may be highly artistic, but it is contrary to the spirit of modern science. Indeed, much of the lack of sympathy that exists between men of extremely artistic and extremely scientific temperament is due to this difference of instinctive attitude towards the world of phenomena.

It is well known that in their development the biological have

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[2] "L'Evolution Créatrice," 4th edition, 1908, pp. 357, 358.

always lagged behind the physical sciences. This is attributable in large measure, of course, to the greater complexity of organic phenomena, but I suspect that the fact that animals and plants admit of an arrangement in generic and specific categories, which seem at first sight to be in singular harmony with the spirit of ancient science and philosophy, may be to a considerable extent responsible for the stolid conservatism of systematic biology. At a time when the physical sciences, through the labors of Kepler, Gallilei and Newton, had already become modern sciences in the true sense of the word, biology was still practically in the Greek stage. This is certainly true of zoology and botany proper up to the middle of the last century, although zoology had through medicine contracted some of the modern spirit, since by that time anatomy and physiology had definitively abandoned Greek and scholastic methods.

At this juncture appeared Darwin's "Origin of Species." The effect of this work was in the first instance destructive, for it tended to dissolve and mobilize the rigid conceptual schematism that dominated, not only the zoology and botany, but the whole cosmology of the time. The conception of an evolution which melted all living beings, man included, into a single vital stream, surging on into the future as it has surged through the æons of the past, continually creating new and destroying old forms, could not fail to clash with the conception of a world created once for all and since engaged very largely in marking time. According to the old view, living objects are more or less vitiated Platonic ideas or Aristotelian forms, according to the new they are eddies or whirlpools in a living current that modify and regulate their movements according to the obstacles, *i. e.*, the "environment" which they encounter. No wonder men like Cuvier declined to accept the doctrine of evolution when it was first promulgated by Lamarck, and that von Baer and Louis Agassiz regarded its rehabilitation by Darwin as a heresy. All of these men believed in the existence of permanent types of organic structure, which, after all, were merely Platonic ideas parading under assumptions more or less theological, privileged moments or aspects of animal and plant morphology interpreted as thoughts of the Deity. It is quite unnecessary to mention the innumerable scholastic and theological opponents of evolution. Their animosity certainly had and still has other motives than a predilection for the Mosaic account of creation.

It is far pleasanter to contemplate the constructive aspects of Darwin's work. Since evolution, as conceived by him, admitted of a mechanical explanation — for survival through natural selection is mechanical and not teleological like survival through psychical effort as postulated by Lamarck—it breathed the spirit of the physical sciences and therefore allied itself with these rather than with psychology and philosophy. When presented with Darwin's conception of evolution, the botanist and zoologist could no longer remain satisfied with mere contemplation of privileged moments. It became necessary to attend to every aspect of the organism. Every phase of its development from the egg to its dissolution, and every particle of its structure had to be submitted to the closest examination, for no character—so ran the theory—was too insignificant to decide whether a species could survive in the struggle for existence. Indeed, even vestigial and rudimental characters began to assume an astonishing importance as witnessing to the past and prefiguring the future history of the species. Such close scrutiny of the entire life-cycle and structure of organisms was also necessitated by Darwin's assumption that the evolution of organic forms is a very gradual process, requiring enormous periods of time. Hence the incentive to record the minutest variations and adaptations and to search for their causes. From the same source sprang the inspiration to study the lower animals and plants with the utmost care and in all their aspects, for these forms—according to the theory—had departed least from the first, simple beginnings of life on our planet, and might, therefore, be expected to throw light on the initial movements of organic evolution. But the animals at the other end of the organic scale were not to be neglected, for the theory which made man a blood relation of the higher mammals could not fail to arouse universal interest in these and all the other vertebrates. And not only did it become necessary to investigate the plants and animals *now* living on the earth, but the strata of the planet had to be ransacked for evidences of past evolutionary history. Paleontology was born anew, and the distribution of life in the present and past became a subject of absorbing and ardent study. Even the most conservative branch of biology, the classification of animals and plants, was shaken to its foundations by the theory of evolution, for under its solvent action the old conceptions of the genus and species, and all the other taxonomic categories, lost their rigid outlines and became fluid and dynamic. In proof of all these statements concerning the immediate effects of the promulgation of the theory of evolution, we have only to glance at the marvelous development during the past fifty years of anatomy, embryology, histology, cytology and physiology, both human and comparative, and of paleontology, chorology, ethology and taxonomy, both botanical and zoological.

The constantly increasing tendency during the past half century to substitute a careful genetic study, that is, a study of all the stages of the life-processes, with a view to establishing the laws or constants of their occurrence, for the ancient cut and dried methods of defining and classifying concepts obtained from the contemplation of privileged moments in the vital flux, has spread far beyond the confines of biology properly so-called. Psychology, which is the most closely related of all the mental sciences to biology, has been revolutionized. Its students have abandoned the old facultative and associationist schematism and turn with renewed interest to the psychology of emotion, volition and instinct, to animal and child psychology and the normal and pathological psychology of the various human races. Mind is no longer looked upon as a thing, but as a living process, the study of which must be undertaken with far subtler methods than were ever dreamed of by the ancient and mediæval psychologists. Philosophy, ethics and religion, which are all so intimately bound up with psychology, are also at last breaking away from conceptualism and absolutism. This is clearly seen in the works of the pragmatists and humanists, and among theological writings in what has been called modernism. These tendencies of the mental sciences have also reached out into sociology, anthropology, archeology, philology, economics and education. Even the fine arts, though still necessarily addicted to the glorification of certain privileged or dramatic moments, have been seized with the modern scientific craving to multiply these moments indefinitely and thus to increase our delight and interest in the full efflorescence of life and its cosmic setting.

Some may doubt whether these marvelous changes in all modern intellectual endeavor have been brought about by the doctrine of evolution. Of course, even if Darwin had never lived and if the doctrine of evolution had never been revived, it is certain that the biological sciences would have developed considerably during the past fifty years merely by following in the footsteps and by adopting the methods of physics and chemistry, but that Darwin's thought quickened, exaggerated and dominated this development cannot be doubted. And even if we go so far as to say that natural selection may eventually prove to be an unimportant factor in evolution, to be consigned to the limbo of defunct hypotheses, together with Darwin's views on pangenesis, sexual selection and the origin of species from fluctuating variations, we must, I believe, still admit that the great English naturalist opened up before us a vast new world of thought and endeavor. But for the doctrine of evolution we should still be contemplating living organisms from afar and in a more or less scholastic and theologizing spirit, like the biologists of the first half of the nineteenth century, and not as now, at close range and with a deeper and freer insight into the significance of the minutest details of development, structure and function.

THE HALO OF A HUNDRED YEARS[1] (FEBRUARY, 1809, TO FEBRUARY, 1909)

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UNIVERSITY OF MICHIGAN

IN ordinary circumstances, a humble representative of Wissenschaft der Philosophie, like myself—a pursuer rather than a possessor of knowledge, would deem any poor words of his superfluous on such an occasion, and in an assembly composed chiefly of those who have consecrated their lives to the natural sciences. But, to-night, I am so bold as to proffer claim to a little niche, because we are to make a pregnant pause, and enjoy an interchange of ideas, in commemoration of the illustrious name, services and discoveries of Charles Robert Darwin, who first saw the light at Shrewsbury, on February 12, 1809, that memorable year of memorable infants.

Place aux dames, as if Darwin were not enough, 1809 gave us Elizabeth Barrett Browning, Mary Cowden Clarke, the Shakespeare scholar, and Fanny Kemble, the great actress. In science, it produced Grassmann and Liouville, the eminent mathematicians; the botanists K. H. E. Koch and George Engelmann; the geologist J. D. Forbes; Jakob Henle, the anatomist; Fitch, the economic entomologist; Stöckhardt, the founder of agricultural experiment stations; and Griscom, the physician. Its children made literature immensely their debtor, for, among them were Tennyson, Edgar Allan Poe, Charles Lever, Monckton Milnes (Lord Houghton), Oliver Wendell Holmes, Mark Lemon (the humorist), Edward Fitzgerald, who rendered Omar Khayyam an English classic; Paludan-Müller, an ornament of Scandanavian letters; Giusti, the Tuscan poet, whom his countrymen delight to call the Béranger of Italy; and Nikolaus Becker, author of that famous song, "Der deutsche Rhein." In music we owe it Chopin and Mendelssohn; in art, Diaz de la Peña, the French landscape painter; in history, Hefele, John Hill Burton, Kinglake, Skene, Cronholm, Bruno Bauer, and Michael Horvath, greatest of Hungarian historians; in scholarship, Theodor Benfey and John Stuart Blackie; in theology, Isaac Dorner; and, in practical religion, Selwyn, the influential missionary-bishop of New Zealand. The educationist, Barnard; the jurist, Phillimore; the publicist, William Rathbone Greg; the philanthropist, Miall, and Baron Hausmann, who found Paris brick and left it

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[1] Address of the president of the Research Club of the University of Michigan, on the occasion of the Darwin commemoration.

marble, were born in 1809, like the philosophers Vacherot and Franck, in France; Tari, in Italy; Nielsen, in Denmark; and Bledsoe, in this country. In the arts of war it bore at least four leaders of distinction—Canrobert, marshal of France; Manteuffel, first governor of the *Reichsland* after the fall of Napoleon III.; Dahlgren, the American admiral, an authority on ordnance; and Menabrea, the Italian engineer, an eminent name in the science of fortification. Its most noted diplomatist was Rutherford Alcock, who saw some of the stress that accompanied the introduction of occidental civilization into Japan, and whose bread, cast upon the waters long ago, has returned to such consequence after many days. Finally, as if to round out the universe of human activity, 1809 brought to birth two immortal statesmen—Lincoln, who was born on the same day as Darwin, and Gladstone.

Now notwithstanding the multifarious activities, incalculable influence, and momentous events, connected with these fifty-four names—an extraordinary galaxy—there can be little doubt that, setting aside place and, in particular, nationality, Darwin has laid profoundest hold upon the universal imagination of mankind. And the obvious question arises, why? Let us look at this for a little; it is much easier to ask than to answer.

In this presence, it would be an impertinence on my part were I to wander into the problem of evolution as understood by students of natural science. But, possibly, I may be able to contribute my tiny mite from another standpoint.

We may take it as axiomatic that genius achieves supremacy very rarely against, or without, the cooperant "social mind," and that it pays the price for lone attainment by missing highest rank. To adopt Matthew Arnold's phrase, the man and the moment must agree; or, as Goethe said, only he who unites with the many at the right moment ever becomes great. If I be not far wide of the mark, Darwin enjoyed peculiar fortune in this respect and, thanks to his extraordinary patience, backed by unusual perseverance and devotion, came to enthrone himself amid the master intellects typical of the nineteenth century.

To begin with, then, we must bear in mind that centuries are arbitrary divisions, that no break assails the onward movement of thought, and that every age serves itself upon its successor. The immense displacements, due to the Renascence in the fifteenth century, and to the Reformation in the sixteenth, carried over into the seventeenth; while the seventeenth lived on in the eighteenth, just as the eighteenth, thanks probably to political and social conditions, continued to rule the nineteenth to 1873 (death of John Stuart Mill), say, especially in the English-speaking countries. Indeed, much of the opposition encountered by evolution from the man in the street, and from pseudo-thinkers, may be traced to this simple fact. Nay, we can trace its potent influence in Darwin himself. The main limitation of his theory results from its bondage to the idea of utility—a heritage from the eighteenth century. In illustration of these cross-currents, still inexplicable, recall that Monge, the mathematician, though born in 1746, was essentially a nineteenth century man; so was Lamarck, born two years earlier; so was Erasmus Darwin, even if sixty-nine of his seventy-one years belonged to the heyday of Pope, Johnson and Paley. Similarly, when we face towards the future rather than the past, we find the seminal ideas of the nineteenth century already astir soon after the middle of the eighteenth. Winckelmann, in 1758; Lessing, in 1766; and, more plainly, Herder, in 1786, are apostles of synthetic as opposed to analytic methods, of "life-history" as against mere taxonomy. Listen to Herder, and note how he prophesies the genetic era:

> Among millions of creatures whatever could preserve itself abides, and still after the lapse of thousands of years remains in the great harmonious order. Wild animals and tame, carnivorous and graminivorous, insects, birds, fishes and man are adapted to each other.

And again, on the side now of the human sciences:

> All the songs of primitive peoples turn on actual things, doings, events, circumstances, incidents, on a living, manifold world. All this the eye has seen, and since the imagination reproduces it as it has been seen, it must needs be reproduced in an abrupt fragmentary manner. There is no other connection between the different parts of these songs than there is between the trees and bushes of the forest, the rocks and caverns of the desert, and between the different scenes of the events themselves.

You see the same thing in Goethe's "Iphigenie" (1787), in his "Versuch die Metamorphose der Pflanzen zu erklären" (1790), and his "Zur Morphologie" (1795–1807), above all, in "Faust," erster Theil (1808). Small wonder, then, that the systematic thinkers bred in the same movement, Kant aside, should be dominated by the genetic idea of development; and even Kant, especially in his "Kritik der Urtheilskraft" (1790), to say nothing of the extraordinary prevision of his "Allgemeine Naturgeschichte und Theorie des Himmels" (1755), is not without latent suspicions concerning the direction to be taken by the new tide. To mention none of his other manifold services—of which, in a company of investigators, the part he played at the foundation of the University of Berlin should merit particular remembrance—Fichte's "Der geschlossene Handelsstaat" (1800), originates a line of socio-economic thought thoroughly characteristic of Darwin's epoch, and affiliated sometimes with biology. Schelling's "Einleitung zum Entwurf eines Systems der Naturphilosophie" (1799), as I have tried to show in another place,[2] exercised no little formative power over a group of his countrymen who made important contributions to the early modern phases of physiology, chemistry, botany,

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[2] "The Movement Towards 'Physiological' Psychology," pp. 75 f.

anatomy and medicine. Still, when all is said and done, Hegel shone the bright particular star of the constellation. Indeed, so far as our perplexing proximity permits fair judgment, we must rank him foremost among the systematic thinkers of the nineteenth century. The ceaseless praises and recriminations that have encompassed his memory ever since his death, in 1831, prove no less. Present signs of his returning influence among the Teutonic peoples indicate much the same thing.

But, some one will inquire, what has all this to do with Darwin's hold upon the general imagination? I answer, everything! For while, schooled by long neglect, even contumely, we philosophers have learned to consume our own smoke in comparative silence, you, my scientific colleagues, may be prepared to take the word of one who, perhaps more than any of your coadjutors, possesses the right to speak with authority on the occasion of the Darwin Centennial. Professor H. F. Osborn writes:

> It is a very striking fact that the basis of our modern methods of studying the evolution problem was established not by the early naturalists nor by the speculative writers, but by the philosophers. They alone were upon the main track of modern thought.[3]

Many proofs might be adduced readily. Two mere indications must suffice here. Hegel, for instance, insists, and rightly, that the botanists of his day, obsessed by classification, did not realize the force of Goethe's position, "eben weil ein Ganzes darin dargestellt wurde."[4] Again, Goethe himself formulated Spencer's famous principle about the passage from indefinite, incoherent homogeneity to definite, coherent heterogeneity. Goethe points out:

> The more imperfect a being is the more do its individual parts resemble each other, and the more do these parts resemble the whole. The more perfect the being is, the more dissimilar are its parts. In the former case the parts are more or less a repetition of the whole; in the latter case they are totally unlike the whole. The more the parts resemble each other, the less subordination is there of one to the other. Subordination of parts indicates high grade of organization.[5]

But, like other incalculable human forces, the idealists bore their manifest limitations. And Hegel may be taken as their consecrated representative. Perhaps we may understand this matter best by saying that, after a fashion, he came too soon. His central thesis embodied a theory of universal development, a theory that has had no parallel for boldness and penetration since Plato and his unique pupil, Aristotle. Now, a huge framework of this sort needs multifarious filling in. And one may well admire the temerity of the philosopher when he recalls the condition of knowledge between 1812 and 1816, the years that wit-

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[3] "From the Greeks to Darwin," p. 87.

[4] "Naturphil.," p. 489.

[5] "Life of Goethe," G. H. Lewes, p. 358.

nessed the successive volumes of Hegel's masterpiece. All things considered, the physical sciences as we know them now—astronomy, geology, physics and chemistry, as well as mathematics in large part—had hardly begun their latest growth; the biological sciences, in their splendid structure of to-day, were still ahead; while the entire group of human sciences, created mainly by the impetus lent by Hegel himself, in the nature of the case, had not entered upon significant formulation. In a word, the idea of development saturated the intellectual atmosphere; nevertheless, the elaborate and toilsome labor of thinking it through piecemeal for the endless realms of nature, and for the subtlest manifestations of consciousness, lay in the future. Here Darwin, like many another, found his opportunity.

In the second place, he was favored by the situation dominant in the field of science as a whole, no less than by his own preeminently cautious and "concrete" mind. With regard to the latter, we have a characteristic statement from his pen, in the form of a letter to Herbert Spencer, acknowledging a copy of the "Essays." Recall that, not long before, Spencer had been writing to Huxley on the subject of Owen, who was to damn Darwin with faint praise eighteen months after,[6] and had expressed himself as follows:

> I am busy with the onslaught on Owen. I find on reading, the "Archetype and Homologies" is terrible bosh—far worse than I had thought. I shall make a tremendous smash of it, and lay the foundations of a true theory on its ruins.[7]

From one point of view, this is still the nineteenth century against the eighteenth. Darwin's letter, dated 25th November, 1858—one year precisely before the "Origin of Species"—runs thus:

> Your remarks on the general argument of the so-called Development Theory seem to me admirable. I am at present preparing an abstract of a larger work on the changes of species; but I treat the subject simply as a naturalist, and not from a general point of view; otherwise, in my opinion, your argument could not have been improved on, and might have been quoted by me with great advantage.[8]

If Hegel evinced intuitive grasp upon the general framework of development, Darwin's cautious genius led him to exercise superlative perseverance in conquering difficult provinces of the detailed phenomena incidental to evolution.

At the same time, Darwin valued the aid of generalization and

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[6] It is generally understood now that the review of the "Origin of Species" published in the *Edinburgh Review* for April, 1860, was by Owen. At this time, all who have access to it should refresh their memories by reading it. The tone of Spencer's references explains not a little to be found in this critique, especially its concluding emphasis upon the superiority of Cuvier.

[7] "Life and Letters of Herbert Spencer," D. Duncan, Vol. I., p. 112,

[8] *Ibid.*, p. 113.

hypothesis, to which many naturalists, misled by Bacon's thoroughly unscientific temper, had been too averse: Accordingly, the trend of scientific method had become tainted, if not with disastrous consequences, at least with results inimical to progress, as we account means of progress now. This, the former of the two aspects mentioned above, has been delineated admirably by Romanes, from whom, I may say in passing, I derived the only knowledge of Darwin's personality, conveyed at first-hand by a mutual friend, that I possess.

> He nowhere loses sight of the primary distinction between fact and theory; so that, thus far, he loyally follows the spirit of revolt against subjective methods. But, while always holding this distinction clearly in view, his idea of the scientific use of facts is plainly that of furnishing legitimate material for the construction of theories. Natural history is not to him an affair of the herbarium or the cabinet. The collectors and the species-framers are, as it were, his diggers of clay and makers of bricks; even the skilled observers and the trained experimentalists are his mechanics. Valuable as the work of all these men is in itself, its principal value, as he has finally demonstrated, is that which it acquires in rendering possible the work of the architect. Therefore, although he has toiled in all the trades with his own hands, and in each has accomplished some of the best work that has ever been done, the great difference between him and most of his predecessors consists in this—that while to them the discovery or accumulation of facts was an end, to him it is the means. In their eyes it was enough that the facts should be discovered and recorded. In his eyes the value of the facts is due to their power of guiding the mind to a further discovery of principles. And the extraordinary success which has attended his work in this respect of *generalization* immediately brought natural history into line with the other inductive sciences, behind which, in this most important of all respects, she has so seriously fallen. For it was the "Origin of Species" which first clearly revealed to naturalists as a class, that it was the duty of their science to take as its motto, what is really the motto of natural science in general,
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> Felix quit potuit rerum cognoscere causas.
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> Not facts, then, but causes or principles, are the ultimate objects of scientific quest. . . . The spirit of speculation is the same as the spirit of science, namely, as we have just seen, a desire to know the causes of things. . . . And to frame hypotheses is to speculate. . . . The difference between science and speculation is not a difference of spirit; nor, thus far, is it a difference of method. The only difference between them is in the subsequent process of verifying hypotheses. . . . The only danger of speculation consists in its momentum being apt to carry away the mind from the more laborious work of adequate verification; and therefore a true scientific judgment consists in giving a free rein to speculation on the one hand, while holding ready the break of verification with the other. Now, it is just because Darwin did both these things with so admirable a judgment, that he gave the world of natural history so good a lesson as to the most effectual way of driving the chariot of science.[9]

While it may well be impossible to assail Romanes's panegyric, and while it is eminently fitting that we should throb to its mood at this time, Darwin would have been the last man to magnify his own office,

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[9] "Darwin and After Darwin," Vol. I., pp. 4–7 (London, 1892).

or to deny his heritage from predecessors. Just as the Neapolitan philosopher-jurist, Vico (1668–1744), foresaw some of the transitive ideas that thinkers from Herder to Hegel, and philologists from F. A. Wolf and Niebuhr, were to clarify, so, too, Goethe and Erasmus Darwin, Lamarck and Chambers, had substituted evolution for spontaneous generation and special creation ere Darwin's day. But two tasks remained, for whose accomplishment Darwin's endowments of mind and character were to the manner born. First, an enormous accumulation of evidence stood in need. This Darwin furnished on a scale still unparalleled by any single investigator. Second, it was necessary to experiment with tentative and candid applications of the evolution hypothesis, apart altogether from flamboyant allegations that the key to every mystery had been grasped at length. Darwin's scientific conscience, and his eminently sane, self-effacing character, equipped him rarely for these essential services. And, with him, evolution may be said to have attained a poise lost somewhat since, I fear, amid the clash of new theories and rival schools, even nations. After long years devoted to excursions in many fields of intellectual activity, I, at least, have met no one who, with such a heady prospect in plain sight, knew how to hold the balance so true as the author of the "Origin of Species." One might almost go so far as to call him *the* proof, *in propria persona,* of Hegel's profound deliverance: "Not only must philosophy be in harmony with experience, but empirical natural science is the presupposition and condition of the rise and formation of the philosophical science of nature."[10]

And this leads, naturally, to a few words concerning Darwin's circumstances, and his character as a man.

Taken on the whole, his achievement happens to be thoroughly typical of English science, in contrast with German, French, or even Scottish, not to say American, methods. He wrought in an independence of others that amounted almost to loneliness. He seems to have gained no inspiration from his teachers at Edinburgh and at Cambridge from none except Henslow, through whose instrumentality he undertook the famous voyage on the *Beagle.* In 1842, while yet a young man, he retired to Down, in Kent, there to mature his epoch-making investigations "far from the madding crowd," but, nevertheless, to show his age its own express image.

As with so many Englishmen of foremost rank in science, he stood apart from that organization of *Wissenschaft* provided by the institute and academies of France, by the university system in Germany and Scotland. We must think of him, in the main, as we think of Young, who presented his fundamental discoveries on the undulatory theory of light in such obscure ways and channels that they never received due

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[10] "Naturphil.," p. 11.

contemporary recognition; of Dalton, who, working as a private teacher at Manchester, was first appreciated in the University of Glasgow; of George Green, the self-taught Nottingham genius, who anticipated Gauss in elaborating the general mathematical theory of potential function, and who was also made known to European science by my *alma mater;* of Boole, who, though the founder of the science of invariants, taught in "venture" schools at Doncaster and Lincoln, and never climbed higher than the professorship of mathematics at an inconspicuous Irish college;[11] of Faraday and Joule, whose pertinacious, unaided labors were also rated first at their real worth in the University of Glasgow; of the Yorkshire shepherd, Dawson, who made Senior Wranglers at Sedbergh in the last years of the eighteenth century. All these men—and I might name others, like the classical succession of English philosophers—were personalities, not ranking officers in a national syndicate of scientific feudalism. Darwin stood latest in their wonderful, and characteristically English, line. The Englishman's passion for independence, his desire for the free play of idiosyncrasy, may account for this. More powerful, in my judgment, is the fact that the pursuit of science had not become a profession, and with the astonishing consequences noted so caustically by Brewster, in 1830.

> The great inventions and discoveries which have been made in England during the last century have been made without the precincts of our universities. In proof of this we have only to recall the labours of Bradley, Dollond, Priestley, Cavendish, Maskelyne, Rumford, Watt, Wollaston, Young, Davy and Chenevix; and among the living to mention the names of Dalton, Ivory, Brown, Hatchett, Pond, Herschel, Babbage, Henry, Barlow, South, Faraday, Murdoch and Christie; nor need we have any hesitation in adding that within the last fifteen years not a single discovery or invention of prominent interest has been made in our colleges, and that there is not one man in all the eight universities of Great Britain who is at present known to be engaged in any train of original research.[12]

(A *research* club takes due note, I hope!) Science lay in far deeper debt to the unusual endowment of individuals than to the patronage of academies, or the fostering stimulus of universities, true to the highest trust of education. In this connection, then, note finally that Darwin's character furnished an ideal instrument for the continuation of this process, *more Anglicano.*

On the intellectual side, Darwin's character presented a combination, unique in modern times at least, of extensive knowledge, profound sagacity and deliberative caution. His mastery over detail simply overwhelms one. His sense for relationship and consequent power to detect a single principle, no matter how confusing the multiplied phenomena

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[11] Queen's College, Cork.

[12] *Quarterly Review*, Vol. XLIII., p. 327. This article led to the foundation of the British Association. Cf. "The English Utilitarians," Leslie Stephen, Vol. I., pp. 47 f., 112.

might be, lent him the ability that was to restore synthesis to its lost place in scientific method. Still, fertile though he proved along theoretical lines, his caution prevented him from riding off, heedless, upon preconceived notions. In this connection, it is a fact worthy of constant note that he refused to discuss questions about the origin of life, and the genesis of the earliest living organisms—subjects fraught with wandering lights. My own ignorance of the field wherein he labored may lead me into error, but, nevertheless, I do not think I am far wrong when I affirm that the adjuncts of his systematization which have least stood the test of time, thanks to manifold discoveries, his fruitage, were precisely those framed as concessions to the opinions of others. His very inability to dogmatize, and his readiness to enter into the standpoint of colleagues, illustrated his mighty virtue of second thought, nigh in the act of overreaching itself. Accordingly, it makes small difference to what extent further investigation may have complicated the problem of the *means* of evolution; his illuminating and thorough presentation of the *fact* stands untouched. The dilemma becomes plainer every day—either evolution, or irrational chaos.

On what may be called the ethical side, his personality exercised immense influence over his intimates and won upon them deeply. A brilliant and witty conversationalist, his refinement and sensitiveness placed even the youngest at ease, while his benevolent wisdom tied men to him by bands stronger than steel. Like all real masters of those who know, he was charmingly unconscious of his eminent genius, and his unaffected modesty led him to see achievements surpassing his own in many a one. What he wrote of Henslow offers a most apposite commentary upon himself.

> Reflecting over his character with gratitude and reverence, his moral attributes rise, as they should do in the highest characters, in preeminence over his intellect.

But, to my mind, the most impressive testimony to Darwin's personal nobility comes, not from any of his devoted friends, but from Leslie Stephen, a critic averse constitutionally from ecstatic praise of any one. He even says: "I should like to succeed in praising somebody some day."[13] Remember, too, that Stephen was on terms of familiarity with the chief figures of the Victorian era, that his own family had produced men of high distinction, and that he married a daughter of Thackeray. Yet, temperament and opportunity notwithstanding, Darwin overtopped all others with him. The venerable naturalist had been to see him in London, and Stephen writes to Charles Eliot Norton, in 1877:

> You may believe that I was proud to welcome him, for of all eminent men that I have ever seen he is beyond comparison the most attractive to me. There is something almost pathetic in his simplicity and friendliness.

[13] "The Life and Letters of Leslie Stephen," p. 307.

> I heard a story the other day about a young German admirer, whom Lubbock took to see him. He could not summon up courage to speak to the great man; but, when they came away, burst into tears. That is not my way; but I can sympathize to some extent with the enthusiastic Dutchman.[14]

Although Darwin must have been tried sorely by vulgar misrepresentation, partisan spite, ignorant invective and foul traduction, "he never took an ill-natured view of any one's character." His conduct midmost the cataract of abuse let loose upon the "Origin of Species" constitutes a glorious monument to his elevation of soul. His open simplicity earned the reverence no less than the affection of those who were privileged to know him. And, as we now place our bays upon his crowned memory, we may adopt the words of the Scottish poet, an acquaintance of my college days, whose sonnet voices the truth so finely:

Man's thought is like Antæus, and must be
Touched to the ground of Nature to regain
Fresh force, new impulse, else it would remain
Dead in the grip of strong Authority.
But, once thereon reset, 'tis like a tree,
Sap-swollen in spring-time: bonds may not restrain;
Nor weight repress; its rootlets rend in twain
Dead stones and walls and rocks resistlessly.

Thine then it was to touch dead thoughts to earth,
Till of old dreams sprang new philosophies,
From visions systems, and beneath thy spell
Swiftly uprose, like magic palaces,—
Thyself half-conscious only of thy worth—
Calm priest of a tremendous oracle!

[14] *Ibid.*, pp. 300, 301.

THE ORIGIN OF THE THEORY OF NATURAL SELECTION[1]

By Dr. A. R. Wallace

I BEG to thank the council of the Linnean Society for the very great honor they have done me, in coupling my name with that of Charles Darwin on the celebration of this anniversary, and for the still greater and more exceptional honor, of perpetuating my features with those of my illustrious forerunner, upon the medal you have now awarded me.

With your permission I propose to make a few remarks both as to the actual relations between Darwin and myself prior to July, 1858, and also to some peculiarities of our respective life-histories which brought about those relations, and which will, I hope, be both novel and of some general interest.

Since the death of Darwin in 1882, I have found myself in the somewhat unusual position of receiving credit and praise from popular writers under a complete misapprehension of what my share in Darwin's work really amounted to. It has been stated (not unfrequently) in the daily and weekly press, that Darwin and myself discovered "natural selection" simultaneously, while a more daring few have declared that I was *the first* to discover it, and that I gave way to Darwin!

In order to avoid further errors of this kind (which this celebration may possibly encourage), I think it will be well to give the actual facts as simply and clearly as possible.

The *one fact* that connects me with Darwin, and which, I am happy to say, has never been doubted, is that the idea of what is now termed "natural selection" or "survival of the fittest," together with its far-reaching consequences, occurred to us *independently,* and was first jointly announced before this society fifty years ago.

But, what is often forgotten by the press and the public, is, that the idea occurred to Darwin in October, 1838, nearly twenty years earlier than to myself (in February, 1858); and that during the whole of that twenty years he had been laboriously collecting evidence from the vast mass of literature of biology, of horticulture and of agriculture; as well as himself carrying out ingenious experiments and original observations, the extent of which is indicated by the range of subjects discussed in his "Origin of Species," and especially in that wonderful store-house of knowledge—his "Animals and Plants under Domestica-

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[1] Reply on receiving the Darwin-Wallace medal of the Linnean Society of London on July 1, 1908.

tion," almost the whole materials for which works had been collected, and to a large extent systematized, during that twenty years.

So far back as 1844, at a time when I had hardly thought of any serious study of nature, Darwin had written an outline of his views, which he communicated to his friends Sir Charles Lyell and Dr. (now Sir Joseph) Hooker. The former strongly urged him to publish an abstract of his theory as soon as possible, lest some other person might precede him—but he always refused till he had got together the whole of the materials for his intended great work. Then, at last, Lyell's prediction was fulfilled, and, without any apparent warning, my letter, with the enclosed essay, came upon him, like a thunderbolt from a cloudless sky! This forced him to what he considered a premature publicity, and his two friends undertook to have our two papers read before this society.

How different from this long study and preparation—this philosophic caution—this determination not to make known his fruitful conception till he could back it up by overwhelming proofs—was my own conduct. The idea came to me, as it had come to Darwin, in a sudden flash of insight: it was thought out in a few hours—was written down with such a sketch of its various applications and developments as occurred to me at the moment,—then copied on thin letter-paper and sent off to Darwin—all within one week. *I* was then (as often since) the "young man in a hurry"; *he*, the painstaking and patient student, seeking ever the full demonstration of the truth that he had discovered, rather than to achieve immediate personal fame.

Such being the actual facts of the case, I should have had no cause for complaint if the respective shares of Darwin and myself in regard to the elucidation of nature's method of organic development had been thenceforth estimated as being, roughly, proportional to the time we had each bestowed upon it when it was thus first given to the world—that is to say, as twenty years is to one week. For, he had already made it his own. If the persuasion of his friends had prevailed with him, and he had published his theory, after ten years'—fifteen years'—or even eighteen years' elaboration of it—*I* should have had no part in it whatever, and *he* would have been at once recognized, and should be ever recognized, as the sole and undisputed discoverer and patient investigator of the great law of "natural selection" in all its far-reaching consequences.

It was really a singular piece of good luck that gave to me any share whatever in the discovery. During the first half of the nineteenth century (and even earlier) many great biological thinkers and workers had been pondering over the problem and had even suggested ingenious but inadequate solutions. Some of these men were among the greatest intellects of our time, yet, till Darwin, all had failed; and it was only

Darwin's extreme desire to perfect his work that allowed me to come in, as a very bad second, in the truly Olympian race in which all philosophical biologists, from Buffon and Erasmus Darwin to Richard Owen and Robert Chambers, were more or less actively engaged.

And this brings me to the very interesting question: Why did so many of the greatest intellects fail, while Darwin and myself hit upon the solution of this problem—a solution which this celebration proves to have been (and still to be) a satisfying one to a large number of those best able to form a judgment on its merits? As I have found what seems to me a good and precise answer to this question, and one which is of some psychological interest, I will, with your permission, briefly state what it is.

On a careful consideration, we find a curious series of correspondences, both in mind and in environment, which led Darwin and myself, alone among our contemporaries, to reach identically the same theory.

First (and most important, as I believe), in early life both Darwin and myself became ardent beetle-hunters. Now there is certainly no group of organisms that so impresses the collector by the almost infinite number of its specific forms, the endless modifications of structure, shape, color and surface-markings that distinguish them from each other, and their innumerable adaptations to diverse environments. These interesting features are exhibited almost as strikingly in temperature as in tropical regions, our own comparatively limited island-fauna possessing more than 3,000 species of this one order of insects.

Again, both Darwin and myself had, what he terms "the mere passion of collecting,"—not that of studying the minutiæ of structure either internal or external. I should describe it rather as an intense interest in the mere *variety* of living things—the variety that catches the eye of the observer even among those which are very much alike, but which are soon found to differ in several distinct characters.

Now it is this superficial and almost child-like interest in the outward forms of living things, which, though often despised as unscientific, happened to be *the only one* which would lead us towards a solution of the problem of species. For nature herself distinguishes her species by just such characters—often exclusively so, always in some degree—very small changes in outline, or in the proportions of appendages, as give a quite distinct and recognizable *facies* to each, often aided by slight peculiarities in motions or habits; while in a large number of cases differences of surface-texture, of color, or in the details of the same general scheme of color-pattern or of shading, give an unmistakable individuality to closely allied species.

It is the constant search for and detection of these often unexpected differences between very similar creatures, that gives such an intellectual charm and fascination to the mere collection of these insects; and when, as in the case of Darwin and myself, the collectors were of a speculative turn of mind, they were constantly led to think upon the "why" and the "how" of all this wonderful variety in nature—this overwhelming, and, at first sight, purposeless wealth of specific forms among the very humblest forms of life.

Then, a little later (and with both of us almost accidentally) we became travellers, collectors and observers, in some of the richest and most interesting portions of the earth; and we thus had forced upon our attention all the strange phenomena of local and geographical distribution, with the numerous problems to which they give rise. Thenceforward our interest in the great mystery of *how* species came into existence was intensified, and—again to use Darwin's expression—"haunted" us.

Finally, both Darwin and myself, at the critical period when our minds were freshly stored with a considerable body of personal observation and reflection bearing upon the problem to be solved, had our attention directed to the system of *positive checks* as expounded by Malthus in his "Principles of Population." The effect of this was analogous to that of friction upon the specially-prepared match, producing that flash of insight which led us immediately to the simple but universal law of the "survival of the fittest," as the long-sought *effective* cause of the continuous modification and adaptation of living things.

It is an unimportant detail that Darwin read this book two years *after* his return from his voyage, while I had read it *before* I went abroad, and it was a sudden recollection of its teachings that caused the solution to flash upon me. I attach much importance, however, to the large amount of solitude we both enjoyed during our travels, which, at the most impressionable period of our lives, gave us ample time for reflection on the phenomena we were daily observing.

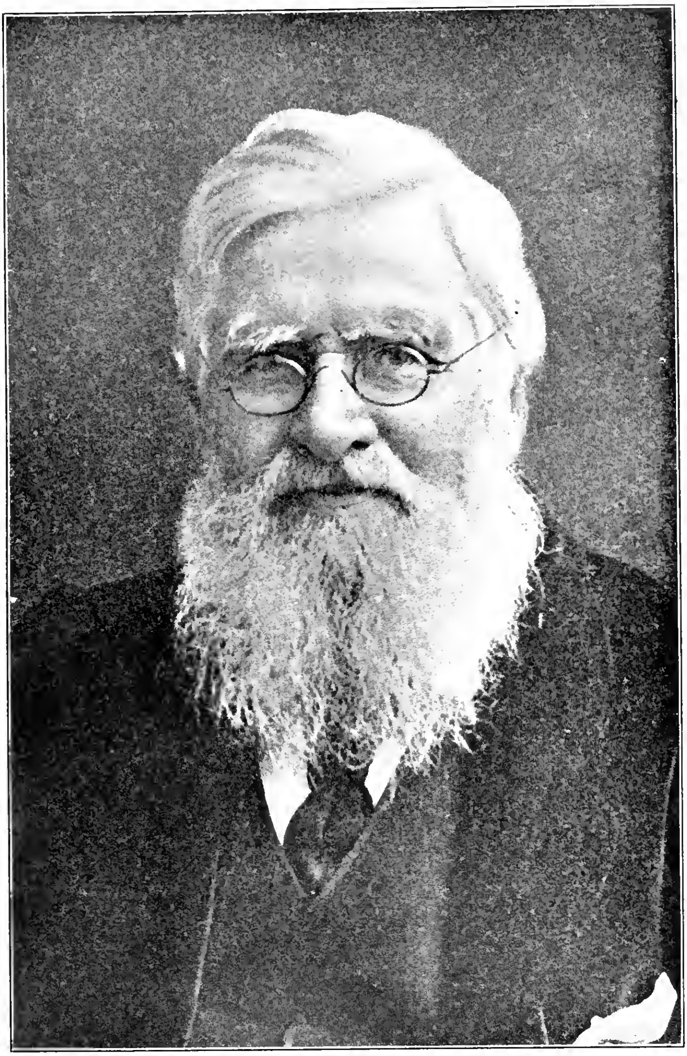
This view, of the combination of certain mental faculties and external conditions that led Darwin and myself to an identical conception, also serves to explain why none of our precursors or contemporaries hit upon what is really so very simple a solution of the great problem. Such evolutionists as Robert Chambers, Herbert Spencer and Huxley, though of great intellect, wide knowledge, and immense power of work, had none of them the special turn of mind that makes the collector and the species-man, while they all—as well as the equally great thinker on similar lines, Sir Charles Lyell—became in early life immersed in different lines of research which engaged their chief attention.

Neither did the actual precursors of Darwin in the statement of the principle—Wells, Matthews or Prichard—possess any adequate knowledge of the class of facts above referred to, or sufficient antecedent interest in the problem itself, which were both needed in order to perceive the application of the principle to the mode of development of the varied forms of life.

And now, to recur to my own position, I may be allowed to make a final remark. I have long since come to see that no one deserves either praise or blame for the *ideas* that come to him, but only for the *actions* resulting therefrom. Ideas and beliefs are certainly not voluntary acts. They come to us—we hardly know *how* or *whence,* and once they have got possession of us we can not reject or change them at will. It is for the common good that the promulgation of ideas should be free—uninfluenced by either praise or blame, reward or punishment.

But the *actions* which result from our ideas may properly be so treated, because it is only by patient thought and work, that new ideas, if good and true, become adopted and utilized; while, if untrue or if not adequately presented to the world, they are rejected or forgotten.

I therefore accept the crowning honor you have conferred on me to-day, not for the happy chance through which I became an independent originator of the doctrine of "survival of the fittest," but, as a too liberal recognition by you of the moderate amount of time and work I have given to explain and elucidate the theory, to point out some novel applications of it, and (I hope I may add) for my attempts to extend those applications, even in directions which somewhat diverged from those accepted by my honored friend and teacher—Charles Darwin.



THE FIRST PRESENTATION OF THE THEORY OF NATURAL SELECTION[1]

By Sir JOSEPH HOOKER

I HAVE been honored by receiving from the council of our society a request that I would take up a little of your time and attention with a brief address. No theme or subject was vouchsafed to me by the council, but, having gratefully accepted the honor, I was bound to find one for myself. It soon dawned upon me that the object sought by my selection might have been that, considering the intimate terms upon which Mr. Darwin extended to me his friendship, I could from my memory contribute to the knowledge of some important event in his career. It having been intimated to me that this was in a measure true, I have selected as such an event one germane to this celebration and also engraven on my memory, namely, the considerations which determined Mr. Darwin to assent to the course which Sir Charles Lyell and I had suggested to him, that of our presenting to the society, in one communication, his own and Mr. Wallace's theories on the effect of variation and the struggle for existence on the evolution of species.[2]

You have all read Francis Darwin's fascinating work as Editor of his father's "Life and Letters," where you will find[3] a letter addressed, on June 18, 1858, to Sir Charles Lyell by Mr. Darwin, who states that he had on that day received a communication from Mr. Wallace written from the Celebes Islands requesting that it might be sent to him (Sir Charles).

In a covering letter Mr. Darwin pointed out that the enclosure contained a sketch of a theory of natural selection as depending on the struggle for existence so identical with one he himself entertained and fully described in manuscript in 1842, that he never saw a more striking coincidence: had Mr. Wallace seen his sketch he could not have made a better short abstract, even his terms standing "as heads of my chapters." He goes on to say that he would at once write to Mr. Wallace offering to send his manuscript to any journal; and concludes: So my originality is smashed, though my book (the forthcoming "Origin of Species"), if it will have any value will not be deteriorated, as all know the labor consists in the application of the theory.

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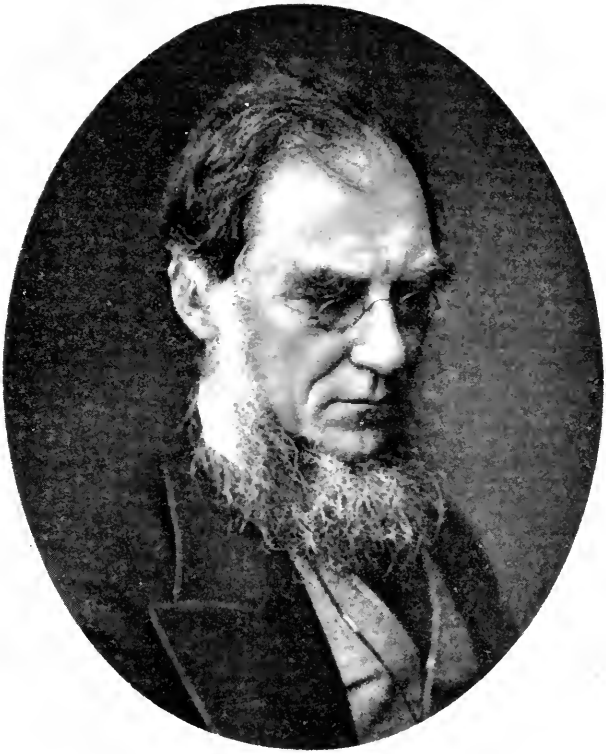
[1] Reply on receiving the Darwin-Wallace medal of the Linnean Society of London on July 1, 1908.

[2] See *Jour. Linn. Soc.*, III. (1859), pp. 45–61.

[3] Vol. II., p. 116.



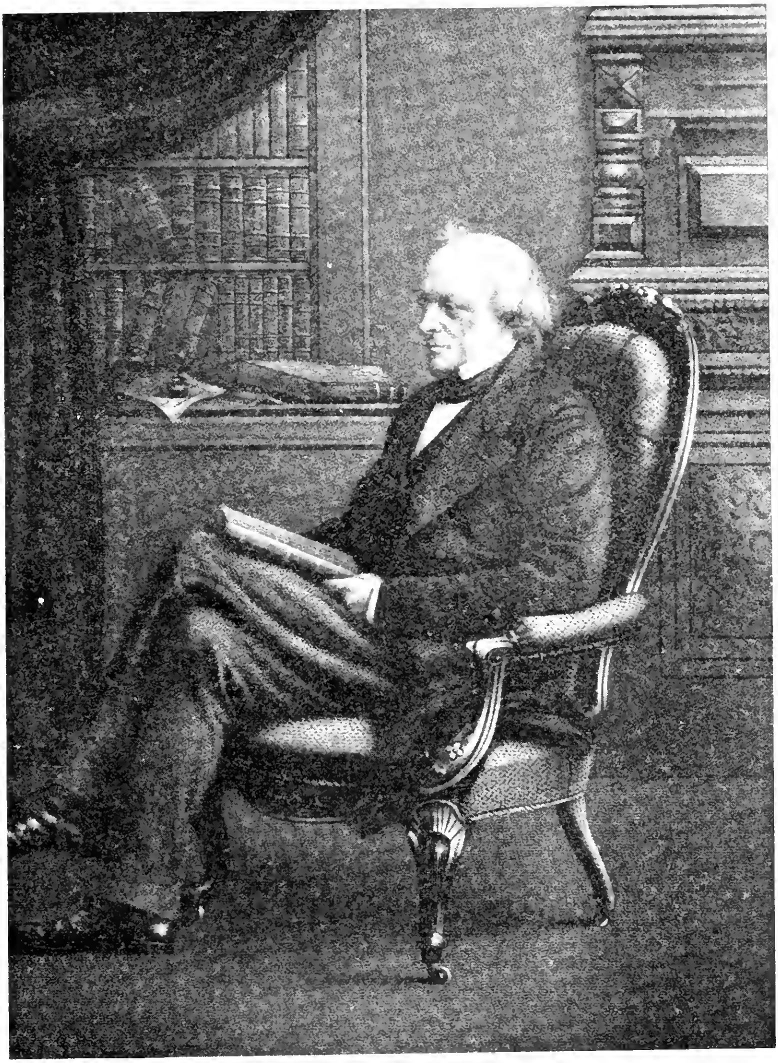
After writing to Sir Charles Lyell, Mr. Darwin informed me of Mr. Wallace's letter and its enclosure, in a similar strain, only more explicitly announcing his resolve to abandon all claim to priority for his own sketch. I could not but protest against such a course, no doubt reminding him that I had read it, and that Sir Charles knew its contents, some years before the arrival of Mr. Wallace's letter; and that our withholding our knowledge of its priority would be unjustifiable. I further suggested the simultaneous publication of the two, and offered—should he agree to such a compromise—to write to Mr. Wallace fully informing him of the motives of the course adopted.

In answer, Mr. Darwin thanked me warmly for my offer to explain all to Mr. Wallace, and in a later letter he informed me that he was disposed to look favorably on my suggested compromise, but that before making up his mind he desired a second opinion as to whether he could honorably claim priority, and that he proposed applying to Sir Charles Lyell for this. I need not say that this was a relief to me, knowing as I did what Sir Charles's answer must be.

At Vol. II., pp. 117, 118 of the "Life and Letters," Mr. Darwin's application to Sir Charles Lyell is given, dated June 26, with a postscript dated June 27. In it he requests that the answer shall be sent to me to be forwarded to himself. I have no recollection of receiving the answer, which is not to be found either in Darwin's or my own correspondence; it was no doubt satisfactory.

Further action was now left in the hands of Sir Charles and myself, we all agreeing that, whatever action was taken, the result should be offered for publication to the Linnean Society.

On June 29, Mr. Darwin wrote to me in acute distress, being himself very ill, and scarlet fever raging in his family, to which an infant son had succumbed on the previous day, and a daughter was ill with diphtheria. He acknowledged the receipt of letters from me, adding, "I can not think now of the subject, but soon will: you shall hear as soon as I can think": and on the night of the same day he writes again, telling me that he is quite prostrated and can do nothing but send certain papers for which I had asked as essential for completing the prefatory statement to the communication to the Linnean Society of his and Wallace's "Essays." This was only forty-eight hours before the reading of the paper laid before the society by Sir Charles and myself on July 1. It may be interesting to recall that the last ordinary meeting of the session of this society is held in the middle of June. The occasion of the meeting on July 1 was exceptional, and was due to the death of the eminent botanist, Robert Brown. As a mark of respect to that great past president, the ordinary meeting of June 17 was adjourned, and a special meeting called in order to elect a successor to the vacancy on the council, caused by his decease, George



Bentham being nominated in his place. The usual election of council and officers had taken place at the anniversary meeting only a month before; and, oddly enough, for the first time among the new members of that body was Charles Darwin. Other papers were also read at the special meeting on July 1, but it will not have escaped your notice that the whole correspondence relating to the two papers on the evolution of species was subsequent to June 17; indeed, the joint letter from Sir Charles Lyell and myself communicating them to the society was only written on June 30.

Thus the death of Robert Brown was the direct cause of the theory of the origin of species being given to the world at least four months earlier than would otherwise have been the case.

The communications were read, as was the custom in those days, by the secretary of ths society. Mr. Darwin himself, owing to his own illness and distress, could not be present. Sir Charles Lyell and myself said a few words to emphasize the importance of the subject; but, as recorded in the "Life and Letters,"[4] although intense interest was excited, no discussion took place: "the subject was too novel and too ominous for the old school to enter the lists before armoring."

It can not fail to be noticed that all these inter-communications between Mr. Darwin, Sir Charles Lyell and myself were conducted by correspondence, no two of us having met in the interval between June 18 and July 1, when I met Lyell at the evening meeting of the Linnean Society; and no fourth individual had any cognizance of our proceedings.

It must also be noted that for the detailed history given above there is no documentary evidence beyond what Francis Darwin has produced in the "Life and Letters." There are no letters from Lyell relating to it not even answers to Mr. Darwin's of June 18, 25 and 26; and Sir Leonard Lyell has at my request very kindly but vainly searched his uncle's correspondence for any relating to this subject beyond the two above mentioned. There are none of my letters to either Lyell or Darwin, nor other evidence of their having existed beyond the latter's acknowledgment of the receipt of some of them; and, most surprising of all, Mr. Wallace's letter and its enclosure have disappeared. Such is my recollection of the day of the fiftieth anniversary of which we are now celebrating, and of the fortnight that immediately preceded it.

It remains for me to ask your forgiveness for intruding upon your time and attention with the half-century old, real or fancied memories of a nonogenarian as contributions to the history of the most notable event in the annals of biology that had followed the appearance in 1735 of the "Systema Naturæ" of Linnæus.

[4] Vol. II., p. 126.

THE PROGRESS OF SCIENCE

DARWIN'S MANUSCRIPT

THERE is here reproduced the text of two pages of the original manuscript of "The Descent of Man" in the handwriting of the author. This manuscript, as well as the portraits by Lock and Whitfield and by Maull and Fox reproduced above, we owe to the kindness of Mr. Charles F. Cox, president of the New York Academy of Sciences, who has permitted the use of his valuable collection of Darwiniana. With the manuscript, the handwriting of which is somewhat reduced in size, is given a transcription, and in the second column the text as it finally appeared in the first edition of the "Descent of Man" as published in 1871, Volume I., pp. 42–43.

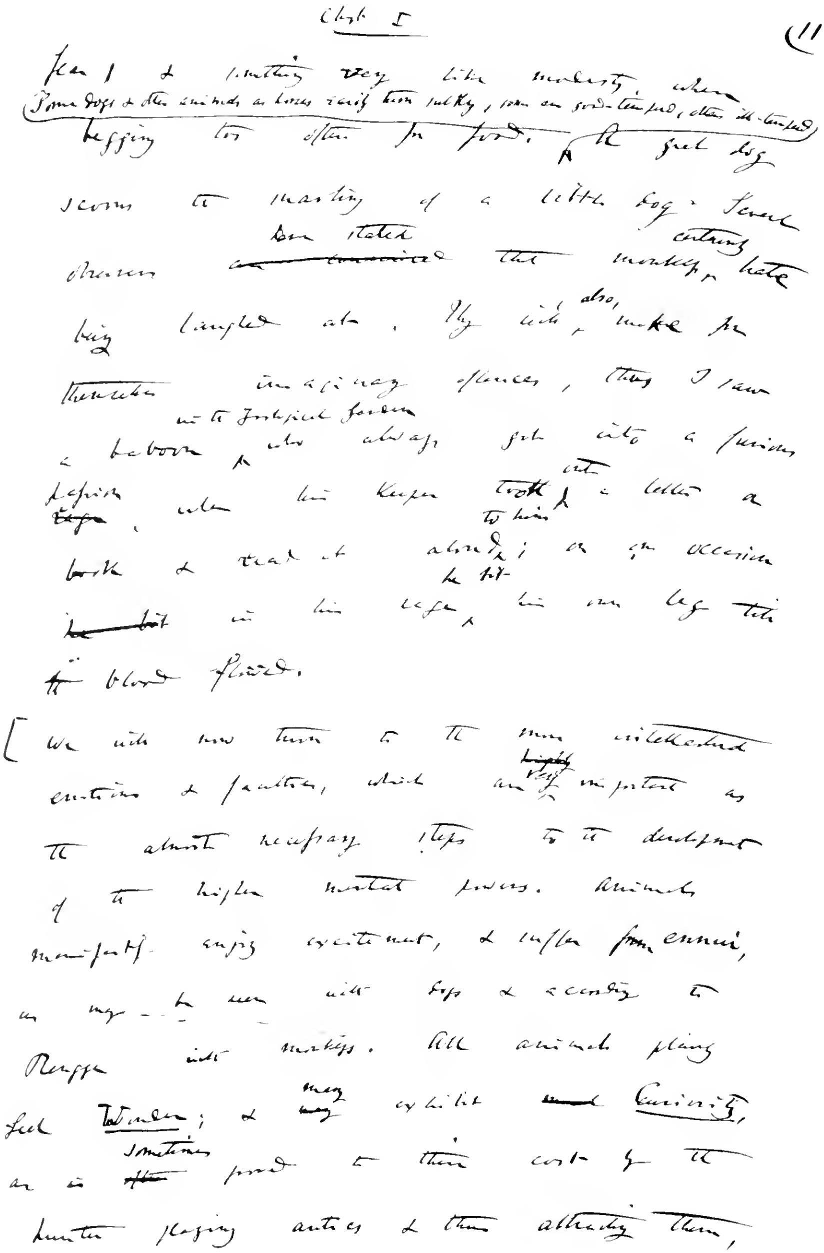
The manuscript shows the great amount of revision which the author made in all his work. It is corrected and interlined, and when it appeared in print it had been largely again rewritten by correcting the proofs. Thus the author evidently expected this matter to appear in Chapter I., but made additions which carried it over into Chapter II. Darwin's daughter, Mrs. Litchfield, who assisted him in the correction of some of his later works, says:

"He did not write with ease, and was apt to invert his sentences both in writing and speaking, putting the qualifying clause before it was clear what it was to qualify. He corrected a great deal, and was eager to express himself as well as he possibly could."

In the "Life and Letters," Mr. Francis Darwin writes:

"Perhaps the commonest corrections needed were obscurities due to the omission of a necessary link in the reasoning, something that he had evidently omitted through familiarity with the subject. Not that there was any fault in the sequence of the thoughts, but that from familiarity with his argument he did not notice when the words failed to reproduce his thought. He also frequently put too much matter into one sentence, so that it had to be cut up into two.

"On the whole, I think the pains which my father took over the literary part of the work was very remarkable. He often laughed or grumbled at himself for the difficulty which he found in writing English, saying, for instance, that if a bad arrangement of a sentence was possible, he should be sure to adopt it. He once got much amusement and satisfaction out of the difficulty which one of his family found in writing a short circular. He had the pleasure of correcting and laughing at obscurities, involved sentences, and other defects, and thus took his revenge for all the criticism he had himself to bear with. He used to quote with astonishment Miss Martineau's advice to young authors, to write straight off and send the MS. to the printers without correction. But in some cases he acted in a somewhat similar manner. When a sentence got hopelessly involved, he would ask himself, 'Now what *do* you want to say?' and his answer written down would often disentangle the confusion."



Chap. I

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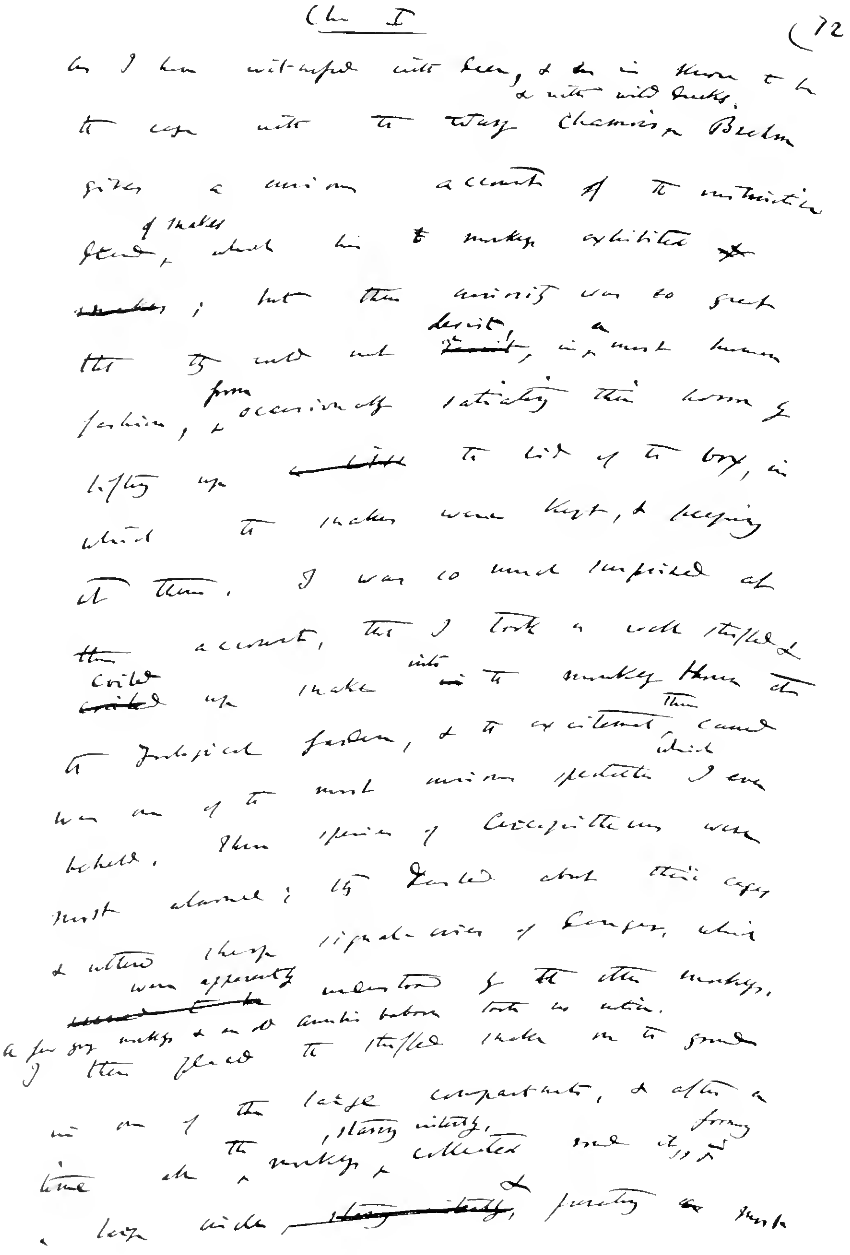
fear, & something very like modesty, when begging too often for food. Some dogs & other animals as horses easily turn sulky, some are good-tempered, others ill-tempered. A great dog scorns the snarling of a little dog. Several observers ~~are convinced~~ have stated that monkeys certainly hate being laughed at. They will also, make for themselves imaginary offences, thus I saw in the Zoological Gardens a baboon who always got into a furious passion ~~rage~~, when his keeper took out a letter or book & read it aloud to him; on one occasion ~~he bit~~ in his rage he bit his own leg till the blood flowed.

[We will now turn to the more intellectual emotions & faculties, which are ~~highly~~ very important as the almost necessary steps to the development of the higher mental powers. Animals manifestly enjoy excitement, & suffer from ennui, as may be seen with dogs & according to Rengger with monkeys. All animals feel Wonder; & many ~~may~~ exhibit ~~and~~ Curiosity, as is ~~often~~ sometimes proved to their cost by the hunter playing antics & thus attracting them, fear & something very like modesty, when begging too often for food. Some dogs and other animals as horses easily turn sulky; some are good-tempered, others ill-tempered. A great dog scorns the snarling of a little dog. Several observers have stated that monkeys certainly hate being laughed at. They will also make for themselves imaginary offenses; thus I saw a baboon in the Zoological Gardens who always got into a furious passion, when his keeper took out a letter or book and read it aloud to him; on one occasion in his rage he bit his own leg till the blood flowed.

We will now turn to the more intellectual emotions & faculties, which are very important as the almost necessary steps to the development of the higher mental powers. Animals manifestly enjoy excitement, & suffer from ennui, as may be seen with dogs & according to Rengger with monkeys. All animals plainly feel *Wonder;* & may exhibit *Curiosity,* as is sometimes proved to their cost by the hunter playing antics and thus attracting them,

There can, I think, be no doubt that a dog feels shame, as distinct from fear, and something very like modesty when begging too often for food. A great dog scorns the snarling of a little dog, and this may be called magnanimity. Several observers have stated that monkeys certainly dislike being laughed at; and they sometimes invent imaginary offences. In the Zoological Gardens I saw a baboon who always got into a furious rage when his keeper took out a letter or book and read it aloud to him; and his rage was so violent that, as I witnessed on one occasion, he bit his own leg till the blood flowed.

We will now turn to the more intellectual emotions and faculties, which are very important, as forming the basis for the development of the higher mental powers. Animals manifestly enjoy excitement and suffer from ennui, as may be seen with dogs, and, according to Rengger, with monkeys. All animals feel *Wonder,* and may exhibit *Curiosity.* They sometimes suffer from this latter quality, as when the hunter plays antics and thus attracts them;



Ch. I

(72

As I have witnessed with deer, & as is known to be the case with the wary Chamois, & with wild ducks, Brehm gives a curious account of the instinctive dread of snakes, which his monkeys exhibited ~~at~~ ~~snakes~~; but their curiosity was so great that they could not desist, in a most human fashion, from occasionally satiating their horror of lifting up ~~the lid~~ the lid of the box, in which the snakes were kept, & peeping at them. I was so much surprised at ~~the~~ account, that I took a well stuffed & coiled ~~coiled~~ up snake into ~~in~~ the monkey House at the Zoological Garden, & the excitement thus caused which was one of the most curious spectacles I ever beheld. Three species of Cercopithecus were most alarmed; they dashed about their cages & uttered sharp signal-cries of danger, which were apparently understood by the other monkeys. ~~[illegible]~~ A few young monkeys & one old Anubis baboon took no notice. I then placed the stuffed snake on the ground in one of the large compartments, & after a time all the monkeys collected round it, forming a large circle ~~staring intently~~, staring intently & presenting a most as I have witnessed with deer, & as is known to be the case with the wary chamois & with wild ducks. Brehm gives a curious account of the instinctive dread of snakes which his monkeys exhibited; but their curiosity was so great that they would not desist, in a most human fashion, from occasionally satiating their horror by lifting up the lid of the box, in which the snakes were kept, & peeping at them. I was so much surprised at this account, that I took a well stuffed & coiled up snake into the monkey House at the Zoological Gardens, & the excitement there caused was one of the most curious spectacles which I ever beheld. Three species of Cercopithecus were most alarmed; they darted about their cages & uttered sharp signal-cries of danger, which were apparently understood by the other monkeys. A few young monkeys and an old Anubis baboon took no notice. I then placed the stuffed snake on the ground in one of the large compartments, & after a time all the monkeys, staring intently, collected around it forming a large circle & presenting a most

I have witnessed this with deer, and so it is with the wary chamois, and with some kinds of wild-ducks. Brehm gives a curious account of the instinctive dread which his monkeys exhibited towards snakes; but their curiosity was so great that they could not desist from occasionally satiating their horror in a most human fashion, by lifting up the lid of the box in which the snakes were kept. I was so much surprised at his account, that I took a stuffed and coiled-up snake into the monkey house at the Zoological Gardens, and the excitement thus caused was one of the most curious spectacles I ever beheld. Three species of Cercopithecus were the most alarmed; they dashed about their cages and uttered sharp signal-cries of danger, which were understood by the other monkeys. A few young monkeys and one old Anubis baboon alone took no notice of the snake. I then placed the stuffed specimen on the ground in one of the larger compartments. After a time all the monkeys collected round it in a large circle, and staring intently, presented a most ludicrous appearance.

PORTRAITS OF DARWIN

In this number of The Popular Science Monthly, commemorating the hundredth anniversary of Darwin's birth, are reproduced eight portraits. The first of these, given as a frontispiece, is from a Woodbury-type made from life by Lock and Whitfield and published in "Men of Mark" by Sampson, Low and Company about 1876. It gives perhaps a better impression of Darwin as he actually looked in his later years than any other portrait. There follows a portrait from a photograph by Maull and Fox taken about 1854. At the same time a similar photograph was made from which a somewhat idealized portrait was engraved in wood for *Harper's Magazine* for October, 1884. The portrait next given appeared in the *Quarterly Journal of Science* in 1866. There then follows a reproduction of an engraving on steel made for *Nature* in 1874 by C. H. Jeens from a photograph taken by O. J. Rejlander about 1870. The next illustration is a photograph of the bronze bust made by Mr. William Couper and presented by the New York Academy of Sciences to the American Museum of Natural History on the hundredth anniversary of Darwin's birth. A second photograph of this bust as it stands on the pedestal is given at the end of the number. The origin of the portrait next given is not known to the editor. The following portrait is from a photograph taken by Mrs. Cameron at the Isle of Wight in 1868. Darwin wrote under it "I like this photograph very much better than any other which has been taken of me." The last portrait is from an engraving on wood by G. Cruels for "The Life and Letters," from a photograph taken by Elliott and Fry in 1881.

There are also given portraits of several of those whose relations to Darwin and his work were especially intimate: Alfred R. Wallace, whose paper on natural selection was presented simultaneously with Darwin's and whose subsequent contributions to the theory of evolution are notable, whom Darwin calls "generous and noble"; Sir Joseph Hooker, the most eminent of British botanists, the life-long friend and scientific adviser of Darwin, of whom he says: "I have known hardly any man more lovable"; Sir Charles Lyell, whose "Principles of Geology" was Darwin's early inspiration and who was later his warm friend and constant adviser, who with Hooker presented to the Linnean Society the papers on natural selection; the Rev. J. R. Malthus, whose "Principles of Population" suggested the idea of natural selection to both Darwin and Wallace, as Lyell's "Principles" had previously impressed on them the idea of evolution; Erasmus Darwin, poet and philosopher, defender of the doctrine of the transmutation of species, whose grandson resembled him in many traits.

ERASMUS DARWIN, M.D. F.R.S.

AUTHOR OF THE LOVES OF THE PLANTS.

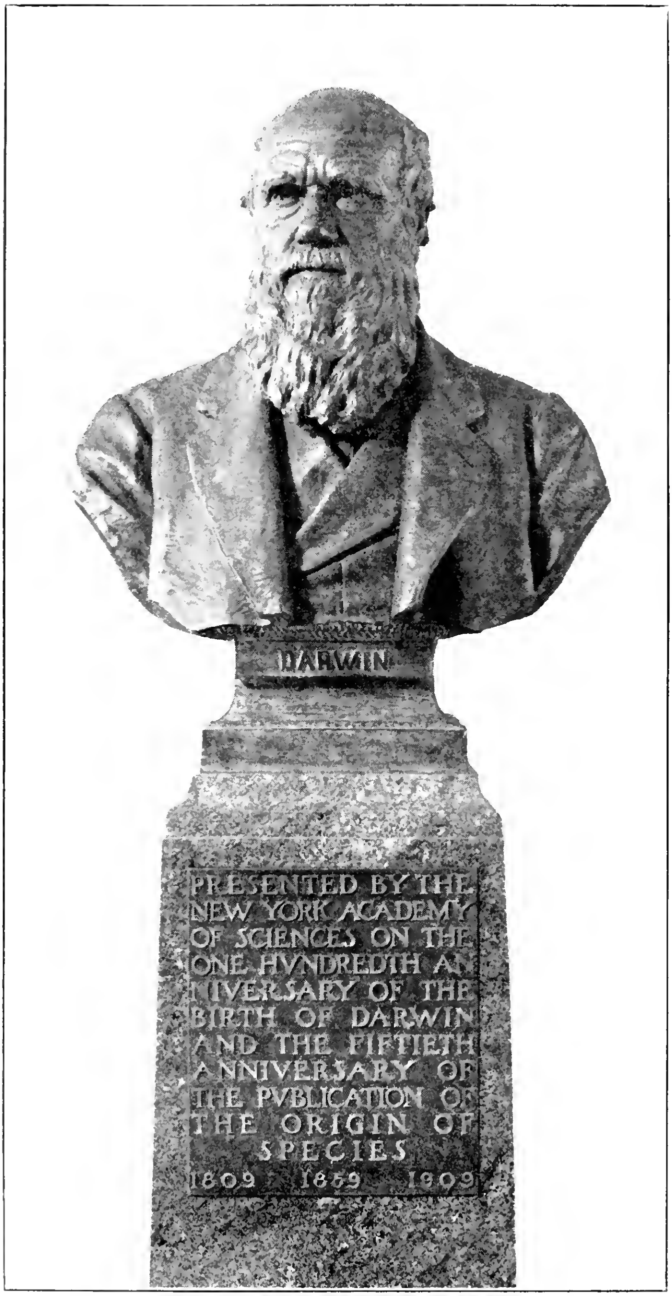
CELEBRATIONS IN HONOR OF THE DARWIN CENTENARY

The most notable celebrations of Darwin's birth and of the fiftieth anniversary of the "Origin of Species" are the exercises of the Linnean Society of London, held on July 1 of last year, and the celebrations to be held at Cambridge in June next. The Darwin-Wallace celebration of the Linnean Society was noted at the time in this journal, and a reproduction was shown of a medal struck in honor of the fiftieth anniversary of the presentation to the society of the papers on natural selection by Darwin and Wallace. These papers were reproduced in the issue of The Popular Science Monthly for November, 1901. The celebrations at Cambridge in June will last several days, and some three hundred universities and learned societies throughout the world will be represented by delegates.

While, as is becoming, the two most elaborate commemorations of the Darwin centenary have been arranged in his own country, celebrations have been more general in the United States than in Great Britain. The most notable exercises were arranged by the American Association for the Advancement of Science and held at Baltimore on January 1. Professor E. B. Poulton, probably the most distinguished living representative of the theory of natural selection, came from England as the guest of the association to make the opening address, and this was followed by a series of papers giving an account of the state of research in the biological sciences based on the doctrine of evolution. These papers are about to be published for the association in a memorial volume by Messrs. Henry Holt and Company.

The commemorative exercises that were perhaps next in interest were held in New York City on Darwin's birthday. The New York Academy of Sciences presented to the American Museum of Natural History a heroic bust of Darwin in bronze by Mr. William Couper, illustrations of which are reproduced in this number of the Monthly. The addresses made on this occasion are printed above. At Columbia University, on the same day, a series of lectures on Charles Darwin and his influence on science was begun, the opening address being printed in this memorial issue.

An equally notable series of lectures on Darwin's influence is being given at Chicago, and commemorative ceremonies and addresses have been arranged not only in large centers, such as Boston and Philadelphia, but also at universities throughout the country. These include Michigan, Cornell, Missouri, Nebraska, Iowa, Iowa State College, Georgia, Brown, Wesleyan and other institutions. In some cases the celebrations extended over several days and as many as ten or more papers and addresses were given.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THE
POPULAR SCIENCE
MONTHLY.

MAY, 1909

THE TYPE OF THE PANAMA CANAL

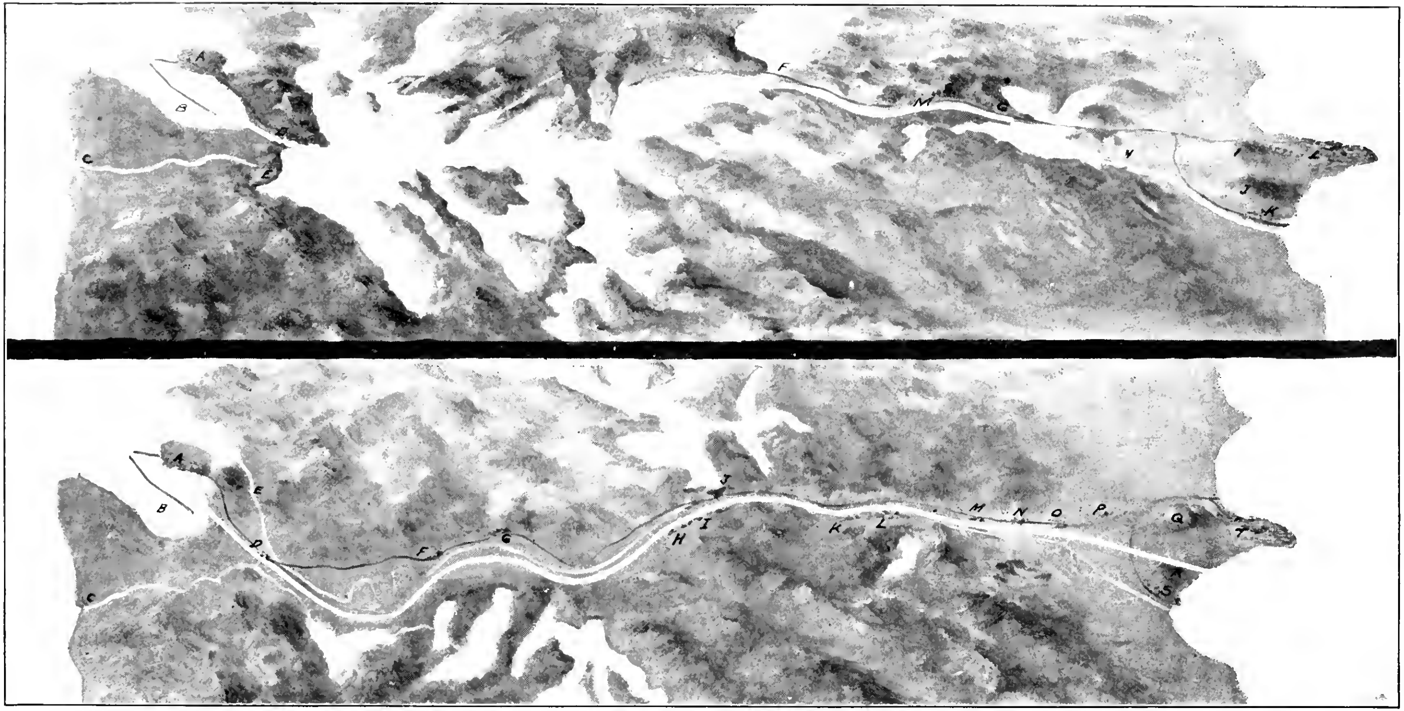
By C. E. GRUNSKY
MEMBER OF THE ISTHMIAN CANAL COMMISSION OF 1904

UNDER the law of June 28, 1902, generally referred to as the Spooner act, which authorizes the construction of an interoceanic canal President Roosevelt appointed, in March, 1904, the following commissioners: Rear Admiral John G. Walker, U. S. Navy (retired), chairman; Major Genl. Geo. W. Davis, U. S. Army (retired); Col. Frank J. Hecker, of Detroit; Major Benjamin M. Harrod, civil engineer of New Orleans; Professor Willam H. Burr, of Columbia University, New York; Wm. Barclay Parsons, of New York: and the writer, of San Francisco.

The Spooner act empowers the president to purchase the canal properties upon the Panama route at a cost not exceeding $40,000,000, or, in the event of failure to do this, to enter into negotiations with the republics of Costa Rica and Nicaragua for a right of way on what is commonly known as the Nicaragua route.

Provision was made for the prosecution of the work of canal construction by the president, acting through and with the aid of a canal commission. An appropriation of $10,000,000 was carried by the act for use upon either of the two routes, and Congress was pledged to make additional appropriations as required up to $135,000,000 in case the Panama route was adopted and not to exceed $180,000,000 for work on the Nicaragua route. The secretary of the treasury is authorized to borrow from time to time, as funds may be required, the sum of $130,000,000, issuing therefor coupon or registered thirty-year bonds in such form as he may prescribe, redeemable after ten years, bearing interest at two per centum per annum.

The passage of the Spooner act by Congress, followed the submission of a report by the canal commission of 1899–1901, which recom-



UPPER SKETCH— LOCK CANAL. *A*, Colon; *B*, Limon Bay; *C*, mouth of Chagres River; *D*, Gatun Locks; *E*, Gatun Dam; *F*, Gamboa; *G*, Pedro Miguel Lock; *H*, Miraflores Locks; *I*, Ancon Hill; *J*, Sosa Hill; *K*, La Boca; *L*, Panama; *M*, Culebra Cut.

LOWER SKETCH SEA LEVEL CANAL. *A*, Colon; *B*, Limon Bay; *C*, mouth of Chagres River; D, Gatun; E, Chagres Diversion; F, Bohio; *G*, Frijoles; *H*, Gorgona; *I*, Matachin; *J*, Gamboa Dam; *K*, Empire; *L*, Culebra; *M*, Paraiso; *N*, Pedro Miguel; *O*, Miraflores; *P*, Corozal; *Q*, Ancon Hill; *R*, Sosa Hill; *S*, La Boca; *T*, Panama.

mended the acquisition by the United States of the rights and properties of the New Panama Canal Company. This recommendation was the direct result of an offer of the canal company to sell all its rights and properties for the sum of $40,000,000. The actual transfer of the canal properties to the United States took place on May 1, 1904.

The great engineering question before the commission, above named, related to the type of canal. Should the canal be built at sea-level or should it cross the backbone of the isthmus at the elevation suggested by the investigating commission of 1899–1901, and apparently contemplated by the Spooner act, with a summit level at 85 feet, or should it be a lock canal with some other elevation of its summit section? This question and the administration's course in setting aside the recommendation of a majority of the board of consulting engineers and adopting the plan of a lock-canal with a summit at the elevation suggested by the commission of 1899 and advocated by the minority members of the board of engineers are still fruitful of discussion.

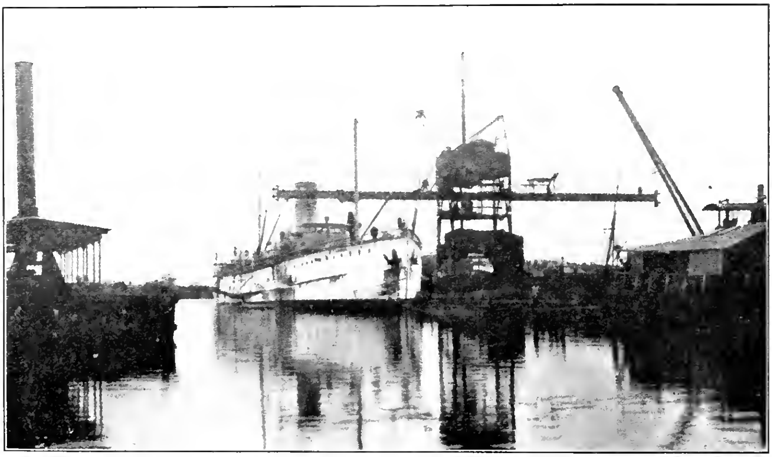
A review of the proceedings leading to the solution, and a presentation of some of the physical features of the problem, as disclosed by the proceedings, may prove an aid to a better understanding of the present situation.

Relating to the kind of canal to be constructed the law provides:

> The President shall then, through the Isthmian Canal Commission . . . cause to be excavated, constructed and completed, utilizing to that end, as far as practicable, the work heretofore done by the New Panama Canal Company, of France, and its predecessor company, a ship canal from the Caribbean Sea to the Pacific Ocean. Such canal shall be of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use, and such as may reasonably be anticipated, and shall be supplied with all necessary locks and other appliances to meet the necessities of vessels passing through the same from ocean to ocean. . . .

It was recognized by the commission of 1904 that under the Spooner act as quoted, a departure, to some extent at least, from the project which the earlier commission had outlined as a basis for comparative cost estimates was authorized and proper. It was incumbent upon the commission to determine whether a canal with summit level at 80 or 60 or 30 feet would not, all things considered, be better than the canal with summit level at 85 feet. It was therefore necessary to regard the entire question of type of canal an open one to be solved by the selection of that type and that summit elevation which would best fulfill all requirements. It was realized that this question required careful consideration from every standpoint, particularly in relation to its serviceability, to time required for construction, to first cost and to the cost of operation and maintenance with due regard to the importance of early completion, and reliability of service after completion.

In entering upon a preliminary discussion of these matters the lack



SEAGOING SUCTION DREDGE *Ancon* TAKING ON COAL NEAR DRY DOCK AT CRISTOBEL.
This and other photographs are from the Annual Reports of the Commission.

of adequate data was sorely felt by the members of the commission and it was soon found that no satisfactory conclusion could be reached without supplementing by additional exploration with the auger and otherwise, the information disclosed by records of surveys, borings and shafts, which had been made by the engineers of the French canal companies. There had been no explorations to sea-level by shaft or by borings in the central sections of the canal yet this information was now of paramount importance for the determination of safe slopes for the sides of the deep cuts. In the absence of such information no satisfactory conclusion could be reached relating to the amount of material that would have to be excavated to maintain a great open cut at Culebra. The side slopes of this cut must be so flat that they will stand permanently. They should be as steep as they can safely be held in order that the quantity of excavation may not be unnecessarily increased. For the solution of this problem, it was necessary to know not only the character of all material to be encountered down to sea-level, but to a depth of over 40 feet below sea-level. Incomplete or unreliable data would throw more or less doubt upon the conclusions reached.

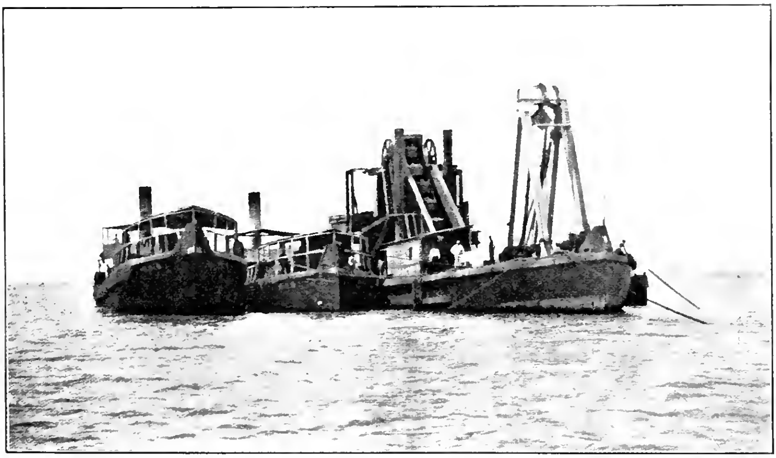
The commission of 1904, therefore, entered at once upon the collection of additional data and hoped to be able to reach an intelligent conclusion relating to the type of the canal at an early date. The published proceedings of the commission show that on December 8, 1904, seven months after the United States had taken possession of the canal properties, it was resolved to send the committee on engineering, consisting of Professor W. H. Burr, Wm. Barclay Parsons, and Major B. M. Harrod to the isthmus

> to see that the necessary surveys and data for determining the type of canal have been completed and to bring the same to Washington to be laid before the commission; and that the committee on engineering plans shall, if possible, recommend to the commission, during March, various plans and estimates for the several types of canal, so that the commission as a whole may determine the same.

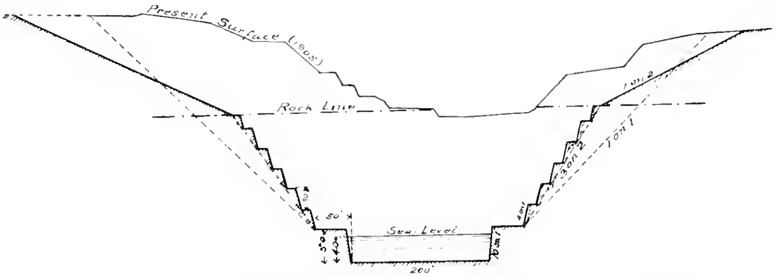
The writer was a fourth member of the committee on engineering plans.

In compliance with this resolution two members of the committee, Professor Burr and Mr. Parsons, went to the isthmus, where their deliberations were participated in by General Davis, who by virtue of his station on the isthmus was a member of all committees there in session. Major Harrod did not accompany the other members of the committee, because it was necessary to preserve a quorum of the commission at Washington for the transaction of business.

On February 23, 1905, the committee, having returned from the isthmus, made a report, in which it recommended that the construction of a breakwater at the entrance of Limon Bay should be commenced at the earliest practicable date: that the harbor at Cristobal should be deepened and otherwise improved; that, if a lock-canal be constructed the summit level of the canal should not exceed 60 feet; that Chagres River should be controlled by a dam at Gamboa; and that a plan for a sea-level canal, free from the restriction of locks (except a tidal lock near the Pacific Ocean) should be adopted. The committee included in its recommendations 150 feet as the least bottom-width of the canal and 35 feet as the least depth, suggesting, however, that estimates be also made to cover a depth of 40 feet. The committee also took up the question of the necessary lock dimensions, if locks be required, and advocated a width of 100 feet and a usable



Old French Ladder or Elevator Dredge deepening Entrance Channel in the Pacific near La Boca. This dredge is being served by two old French self-propelling hopper barges, known as "clapets."



Typical Cross Section adopted by the Board of Consulting Engineers for the Culebra Cut. K. 54.41.

length of 1,000 feet, but with intermediate gates to conserve time and water. The committee called attention to the increasing difficulties of constructing a dam at or near Bohio, disclosed by additional borings, and condemned as impracticable a dam at Gatun where borings to 172 and to 139 feet below sea-level did not reach bed-rock.

The data, which the commission had instructed the committee to bring to Washington, were not submitted with the report, neither did such data accompany a progress report of the chief engineer, Mr. John F. Wallace, which was received a few weeks later. The type of canal was, however, quite fully discussed by Mr. Wallace, and his report contained the recommendation

> that no temporary or tentative plan be adopted that will interfere with the final adoption of the "sea-level plan," which it is hoped will ultimately receive the favorable consideration of the commission.

The committee report, however, brought before the commission a definite recommendation, relating to the type of the canal. In the

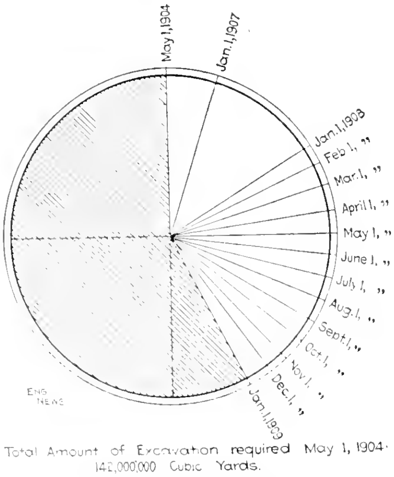


Fig. 1. Progress of Excavation on the Panama Canal under the United States, as Compared with Total Excavation Required.

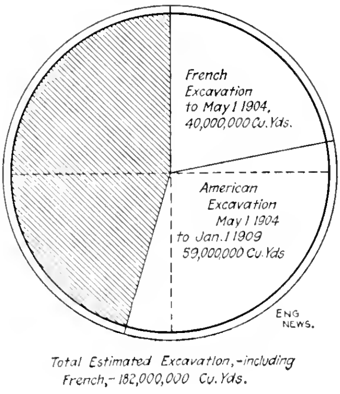


Fig. 2. Diagram showing Relation of French and American Excavation on Panama Canal to Total Estimated Amount.

absence of the data necessary to reach a final conclusion on this point, and in view of the fact that no embarrassment would result from a deliberate weighing of all the facts, the writer, though with a pronounced leaning toward the sea-level type, could not see his own way clear to an immediate concurrence in the conclusions of the committee. There was nothing convincing either in the report of the chief engineer nor in the report of the committee relating to quantity of material to be excavated nor in relation to probable cost. The writer did not then believe, nor does he now believe, that the steep slopes where the cut is deepest, as suggested by the committee, nor as incorporated in the plans now being carried out, can be adhered to.[1] There will have to be taken out ultimately very much more material than heretofore assumed at Culebra. This fact coupled with the concentration of the great mass of the excavation in a relatively short central section of the canal, which rendered preliminary estimates of time and cost of the removal of this material uncertain, was a factor that could not be ignored. When, therefore, at a meeting of the commission in March, 1905, it was proposed by Major Harrod that the recommendation of the committee be adopted and that the commission decide in favor of the sea-level canal the writer was not prepared to go so far and the committee report was referred to the committee on engineering plans, of which he was a member, for further consideration.

From these facts, as recorded in the printed proceedings of the canal commission, it might be inferred that at that time Major Harrod was in favor of the sea-level type of canal and that the writer favored the lock type. But the writer's stand was taken, as explained, to prevent action based on inadequate data, while Major Harrod is found eight months later among the members of the second canal commission who determined that the lock plan of canal, as recommended by the minority of the board of consulting engineers, is the one that should be carried out. And now the writer, after having had several years more time for reflection, and in the light of such additional information as has come to hand, is not yet convinced that the wisest course was pursued by the later commission, by the secretary of war, by the president and by congress when the findings of the majority of the board of consulting engineers, eight to five, were disregarded and the plans for a lock-canal project, as recommended by the minority, were adopted.

Before the committee on engineering plans made a report the Walker commission was superseded by the commission of 1905, whose powers were concentrated in an executive committee of three, at the

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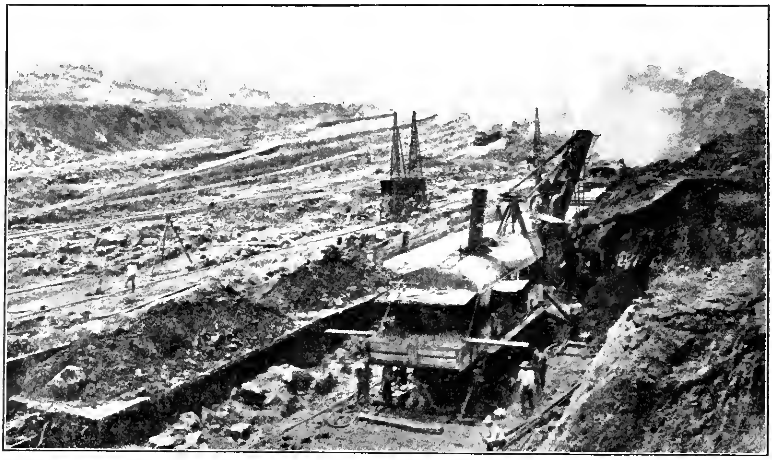
[1] Since this article was written information has been received that there has been much flattening of slopes. The standard section as shown in the illustration elsewhere presented is therefore no longer strictly typical of the section to which the canal will be finished.

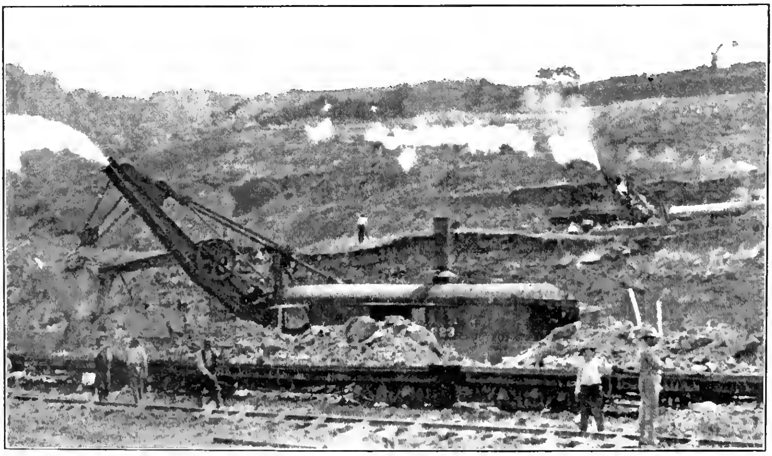


VIEW IN CULEBRA CUT, NEAR EMPIRE, LOOKING SOUTH.

head of which, with dominating influence in the commission's executive affairs, was Mr. T. P. Shonts.

This commission was appointed on April 3, 1905. Two months later President Roosevelt named a board of consulting engineers, to whom he submitted the question of canal type. Thirteen engineers accepted the invitation to participate in the deliberations of this board of engineers.

The board, as finally constituted, consisted of: Geo. W. Davis, Major General U. S. Army (retired), chairman; Alfred Noble, chief engineer of the East River Division P., N. Y. & L. I. R. R.; Wm. Barclay Parsons, chief engineer of the New York Subway; Wm. H. Burr, professor of civil engineering, Columbia University; Henry L. Abbot, Brigadier



STEAM SHOVELS LOADING LEDGERWOOD FLATS ON EAST SIDE OF CULEBRA CUT JUST SOUTH OF GOLD HILL.

General U. S. Army (retired); Frederic P. Stearns, chief engineer of the Metropolitan Water and Sewerage Board, Boston; Joseph Ripley, general superintendent of the St. Mary's Falls Canal; Isham Randolph, chief engineer of the Sanitary District, Chicago; Wm. Henry Hunter, chief engineer of the Manchester Ship Canal; Eugen Tincauzer, Königlich Preussischer Regierungs-und-Baurath, Königsberg, Germany; Adolphe Guérard, inspector général des Ponts et Chausseés, France; E. Quellennec, chief engineer des Ponts et Chausseés and consulting engineer of the Suez Canal Company, France; and J. W. Welcker, Hoofdingenieur, Directeur van den Ryks-Waterstaat, The Netherlands.

On this board of engineers were the three members of the first canal commission,[2] General Davis, Professor Burr and Mr. Parsons, who a few months before had submitted a recommendation favoring a sea-level canal. Other members of the board were known to favor a lock canal. The members of the board therefore naturally fell into two groups of which one was friendly to the sea-level, the other to the lock type of canal, and to the committees appointed from these groups was assigned the task of discussing the canal problem from the two divergent standpoints. The board as a whole, however, passed on certain features in order that the conclusions thus reached might serve as a guide in determining other features of the projects. Thus it was resolved that locks should have a usable length of 1,000 feet, a width of 100 feet and a depth of 40 feet. The board determined, too, upon the type and dimensions of the canal section which should be made the basis of a comparison of cost estimates.

The consulting engineers visited the isthmus and thus learned much, by personal observation, of the conditions under which the canal work must be prosecuted.

As a result of their studies the members of the lock-canal committee of the board of engineers submitted four projects. Two of these were for a canal with a summit level at 60 feet and the other two for a canal with its highest section at 85 feet.

Other projects for the lock-type of canal were presented by Mr. Lindon W. Bates, by Mr. P. Bunau-Varilla and by Major C. E. Gillette, of the engineer corps of the U. S. Army. Mr. Bates presented three projects with a preference expressed for a plan including a terminal lake at each end of the canal, of which the lake at the Atlantic end was to be formed by a dam at Mindi and the lake at the Pacific end by dams from Ancon to Sosa Hill and from Sosa Hill across the Rio Grande. Under this project there would also be an intermediate lake, formed by a dam across the Chagres River at Bohio. The summit level suggested was 62 feet.

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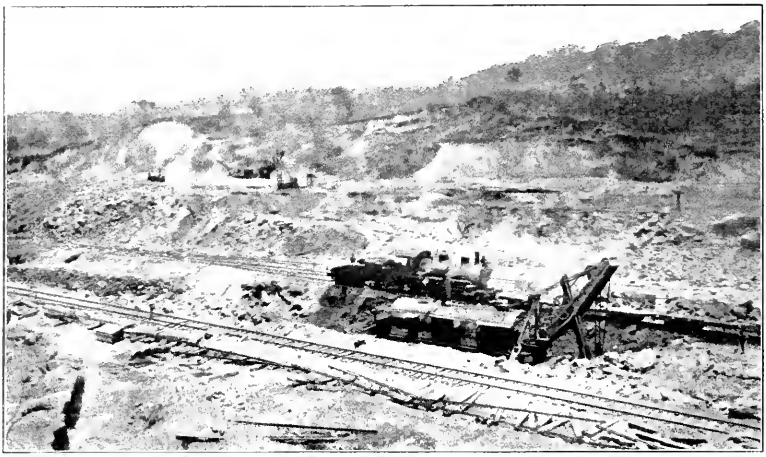
[2] Of the other members of the first commission Admiral Walker had returned to private life. Major Harrod had been named on the second commission and the writer had accepted the position of chief consulting engineer in the Reclamation Service under the Secretary of the Interior.



Las Cascadas Slide, Culebra Division, April, 1908. Area of Slide, 5,433 Square Yards. Estimated amount of material in motion, 100,000 cubic yards. This slide started in the dry season and extended back 230 feet from the edge of cut and to within 50 feet of the crest of the hill.

Mr. Bunau-Varilla, a civil engineer who was at one time chief engineer, of the Panama Canal Company, proposed a project with a summit level at 130 feet; but with all locks so arranged that there could be a gradual progress of excavation and deepening of the summit level with a successive cutting out of locks until finally the lock canal was converted into a sea-level canal.

Major Gillette advocated a lock canal with its highest section at 100 feet above sea-level.

The sea-level canal committee of the board of engineers reported in favor of a canal 40 feet deep, with a bottom width of 150 feet in earth, and side slopes adjusted to the nature of the ground so as to give a surface width of 302 to 437 feet. The bottom width in rock was to be increased to 200 feet and the surface width in rock was to be 208 feet. At the Pacific end the canal was to be protected by a tidal lock located between Ancon and Sosa hills. The plans, as proposed by the committee, included a dam at Gamboa across Chagres River of either masonry alone or of earth and masonry combined. This dam was necessary for the control of the river.

The dimensions of the canal of the committee project at the point of deepest cutting near Culebra are as follows: Bottom width, 200 feet; the banks to have a batter of 1 in 10 rising from the bottom to a berm 10 feet above the water surface; the berm to be 45 feet wide (according to diagram; 50 feet according to text of report); then a succession of bank slopes with a batter of 1 in 4 and a rise each of 30 feet, one above the other, with intermediate berms each 12½ feet wide up to the rock line—shown by a diagram for the point known as Kilometer 51.41 in

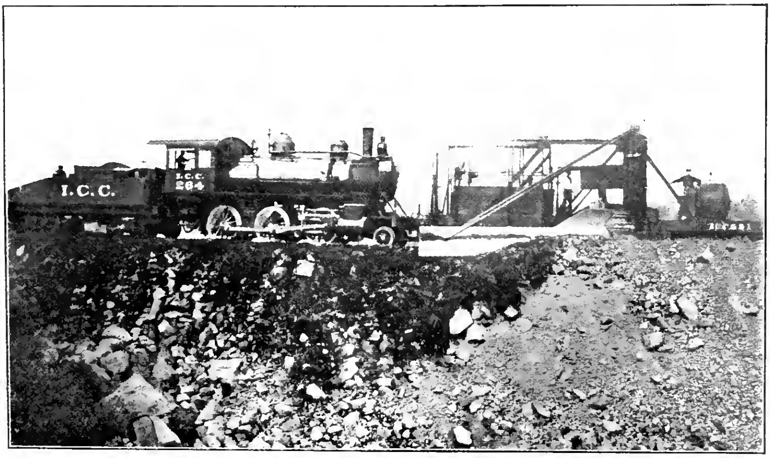
Culebra cut at about 170 feet above the water surface—thence to the natural surface with a rise of one foot in two.

In the course of its deliberations the board of engineers passed favorably upon the feasibility of a canal of either the lock or sea-level type. It determined that a lock canal with summit level at 60 feet should be the basis of comparison of the lock with the sea-level type. It reached the conclusion that about 10 to 11 years should be the time assumed to be necessary for the construction of a lock canal, with summit level at 60 feet, and about 12 to 13 years for the construction of a sea-level canal.

The quantity of material of all kinds to be excavated in constructing a sea-level canal was estimated at 231,026,000 cubic yards, and the estimated cost of making the excavation was $183,136,000.

Among the important considerations bearing upon the selection of the best canal type the board of consulting engineers, as noted in the majority report, says:

> The canal will provide the one great maritime highway, not between seas, but between oceans; not for countries, but for continents. The vastness of the interests to be served by the canal, many of which interests now wait for their development on the construction of the waterway, demands that the canal shall, when opened for traffic, be of the type which will most perfectly fulfil the purposes which the waterway is intended to accomplish.
>
> First and foremost it is essential that the Panama Canal shall present not merely a means of interoceanic navigation, but a means of safe and uninterrupted navigation on which no special hazards will be encountered by and no vexatious delays will be occasioned to the vessels which will traverse it. It is therefore evident that the canal ought to be formed in such manner that the course thereof shall be free from all unnecessary obstructions, and that no obstacles should be interposed in that course, whether temporary or permanent, which would by their very nature be an occasion of peril and of detention to

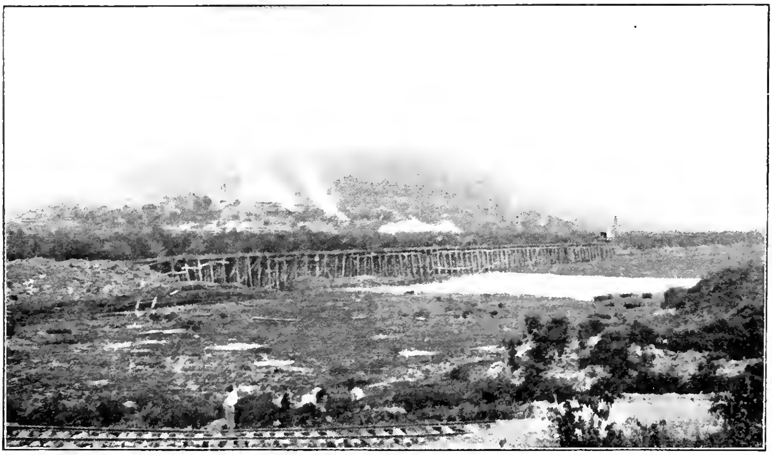


Spreading Material on the Corozal Dump.

passing vessels, and more particularly to vessels of the great size which the Panama Canal is designed to accommodate.

The board is of opinion that this consideration should be of determining force in respect to the type of canal to be adopted, and that it should lead to rejection of all proposed plans in which lift-locks, whether few or many, form the principal or dominating features, and consequently to the acceptance of the sea-level plan as the only one giving reasonable assurance of safe and uninterrupted navigation.

The majority then set forth that no canal with locks can fulfil these requirements and that the sea-level canal is the only type of canal that can give reasonable assurance of safe and uninterrupted navigation. They refer to three accidents in the preceding nine years arising from collisions between steamers and lock gates on the "Soo," and to three accidents of a like nature on the Manchester Canal, and to the disastrous results that would have followed such accidents at the locks of larger dimensions and higher lift on the Panama Canal. They placed the estimated cost of a sea-level canal at less than $250,000,000, and thought that it could be completed in twelve to thirteen years. They strongly condemned any provisional treatment such as the construction of a lock canal.



Trestle Dump just outside of East Toe of the Sosa-Corozal Dam.
Ancon Hill and Ancon Hospital buildings in the background.

It is interesting to find among these members Mr. Hunter, the chief engineer of the Manchester Ship Canal (which is a lock canal), who in a convincing statement explains why, although as a member of the Comité Technique, he favored the lock canal as best suited to the conditions under which the New Panama Canal Company was operating, he is now in favor of the sea-level canal.

As an offset to the recommendation of the majority, a minority of five members, Noble, Abbot, Stearns, Ripley and Randolph favored a lock canal for the following reasons:

> Greater capacity for traffic than afforded by the narrow waterway proposed by the board.
>
> Greater safety for ships and less danger of interruption to traffic by reason of the wider and deeper channels which the lock canal makes possible at small cost.
>
> Quicker passage across the Isthmus for large ships or a large traffic.
>
> Materially less time required for construction.
>
> Materially less cost.

The project recommended by the minority, which is the project as now being carried out (except for an enlargement of the locks, a change of lock locations, and the abandonment of the proposed dams on both sides of Sosa Hill at the Pacific end of the canal), includes a dam at Gatun, but none at Bohio, and no dam at Gamboa. The locks were to be 95 feet wide, 900 feet long, and the depth of water was to be 40 feet. The summit level was fixed at 85 feet.

Under the minority plan there were to be at the Pacific end of the canal duplicate locks of one lift of 31 feet each, and twin locks in flights of two at Sosa Hill.

The time required to construct the lock canal was estimated by the minority at about six years less than would be required for a sea-level canal, and the cost of the canal is estimated by them at $139,705,000. They say in their report:

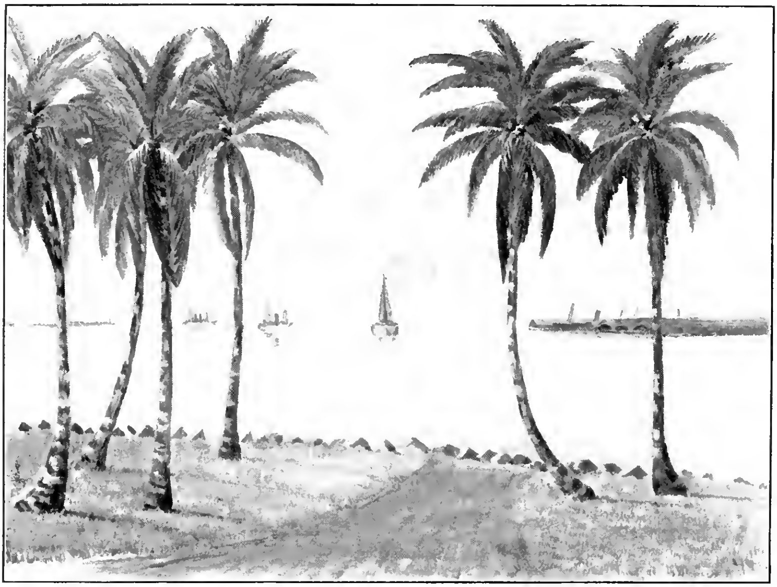
> The greater cost of the proposed sea-level canal—upward of $100,000,000 more than that of the lock canal herein advocated—is not a trifling sum even for the resources of the United States. If such an outlay is incurred a greatly superior waterway should be obtained or the expenditure will be unwise and the result discreditable.

The minority then present their views at length, calling attention to the small risk of injury to a well-equipped canal lock; to the equal facility of protecting the canal against injury in time of war, no matter what its type; to the greater liability of delay and injury to shipping in traversing artificial channels at considerable speed than in moving slowly under perfect control through locks; to the greater speed at which the open water above the locks can be navigated; to the reduced time that will be required in the passage through the canal with locks; to the greater amount of traffic that would at the outset be provided for; to the provisions that can be made to prevent accidents at the locks; to the extraordinary dimensions proposed for the earth dams at Gatun and at Sosa Hill; to the fact that time required to make Culebra cut and to construct the locks is about the same. They estimate that six years less time will be required to build the lock canal than to build a sea-level canal.

At the time, January 10, 1906, the board of consulting engineers submitted their majority and minority reports to the Isthmian Canal Commission, the membership of the commission was as follows: T. P. Shonts, chairman; C. E. Magoon, governor of the Canal Zone; Rear

Admiral Mordecai T. Endicott, civil engineer, U. S. Navy; Brig. Gen. Peter C. Hains, corps of engineers, U. S. Army (retired); Col. Oswald H. Ernst, corps of engineers, U. S. Army (retired); and Benjamin M. Harrod. A vacancy in the commission that had been caused by the resignation of Mr. John F. Wallace had not been filled.

This commission determined on February 5, 1906, by a vote of five to one, to recommend to the president the lock canal project of the minority of engineers. The dissenting member was Admiral Endicott, who favored the adoption of the sea-level project.



LIMON BAY FROM THE DE LESSEPS HOUSE. Sketched April 10, 1904. The ships at anchor are the *Newark*, the *Montgomery* and the *Marietta*, all of the U. S. Navy.

The recommendation of the commission was accompanied by a report of Mr. John F. Stevens, their chief engineer, who favored the lock-canal plan.

The secretary of war approved the recommendation of the commission and the president was not slow in acting. On February 19, 1906, the reports and papers were transmitted to Congress with a statement of his conclusions that the type of canal to be built is the canal with locks.

On June 21, 1906, the senate, by a vote of 36 to 31, passed an act authorizing the construction of a lock canal. This act was a few days later concurred in by the house without division. It provided

> That a lock canal be constructed across the Isthmus of Panama connecting the waters of the Atlantic and Pacific oceans, of the general type proposed by the minority of the board of consulting engineers, created by order of the President under date of January 24 (June 24), 1905, in pursuance of an act

entitled "An act to provide for the construction of a canal connecting the waters of the Atlantic and Pacific Oceans," approved June 28, 1902.

It has already been stated that the minority of the board of engineers recommended that the locks be made 95 feet wide with a usable length of 900 feet. The canal commission determined that larger locks would be desirable and fixed the width at 100 and the usable length at 1,000 feet. This action did not, however, satisfy the U. S. Navy. The question of still larger locks was agitated and resulted in action by the naval authorities upon whose suggestion it was finally decided to increase the width of the locks to 110 feet. The depth of water in the locks is to be about 41.5 feet; this will be the depth in fresh water which will be equivalent to 40 feet in salt water.

Since the final and specific approval of the lock-canal plan by Congress all the work on the isthmus has been directed to the rapid construction of this type of canal. Before presenting a few of the salient facts relating to the progress which has been made, a brief review will be given of the opinion expressed by some of the experts whose views were considered in reaching the conclusion that under all the circumstances it was best to build a lock canal.

It should be stated in this connection that the earlier conclusion of the Comité Technique, which was an advisory body to the New French Canal Company, favoring a lock canal, can be given but little weight, as an influence upon the later conclusion, because the advice of that committee was given to a private company operating under a concession with a time limit, and it was compelled to give paramount weight to the financial aspect. A canal had to be built under restrictions of time and cost, and it was to be made a profitable venture. It is not surprising, therefore, that under the new conditions, one of the members of that committee, Mr. Hunter, is found in 1905, as already stated, among those who advocate the sea-level canal.

Mr. John F. Wallace, a past president of the American Society of Civil Engineers, who was called from the position of chief engineer and manager of the Illinois Central Railroad to the position of chief engineer of the commission of 1904 and was later made a member of the commission of 1905, in addressing the board of consulting engineers pointed out:

> That the most desirable transportation routes are straight and level. Variation from the ideal may become necessary to overcome obstacles of a physical, financial or other nature. The plan usually selected is the one in which the sum obtained by adding the interest on cost of construction to the annual cost of maintenance and operation is a minimum. In the case of the canal the feature of future development should not be overlooked and any variation from the ideal of a straight or sea-level canal should only be made after the most mature and careful consideration and for the gravest of reasons. Minor deflections from a straight line are comparatively immaterial as compared with variations of levels.

NORTHEASTERLY ACROSS THE GATUN DAM SITE. Sketched in 1904.

Mr. Wallace formulates certain propositions which he considers fundamental and others which are essential in arriving at the most desirable plan of canal. He says that the most desirable canal is the sea-level canal of such dimensions as would afford unrestricted passage for the largest vessels afloat, with such margin for increase in size and draft as can reasonably be anticipated, making allowance for unexpected developments. No plan should be adopted that would prevent the ultimate construction of a sea-level canal at least approximately approaching to the final idea of the Straits of Panama. Time and cost should be considered to the extreme limit before determining upon a plan which would interfere with this ultimately desirable accomplishment. It is highly desirable that no dams should be constructed the foundations of which can not be carried to bed rock, or at least impervious curtain connection be made therewith. No high dam should be constructed, the destruction of which, by accident or design, would close navigation through the canal until its restoration. If it is absolutely essential to the project that such dams be constructed, they should retain the lowest possible head of water and be of such a nature as not to require the use of experimental, new or untried methods of construction. If terminal lakes are to be formed, the dams creating them should be as low as possible imposing the minimum weight upon the subsoil. The construction of even a low barrage at the Rio Grande Delta would undoubtedly encounter innumerable difficulties in crossing localities where the sub-formation would be such as to give way under the imposition of the weight of material placed thereon. The same obstacle would probably be met to a greater or less extent in the construction of a dam, particularly a high one, in the vicinity of Gatun. The entire valley to at least a depth of 200 feet is alluvial. It is therefore, highly improbable that in the heterogeneous mass of material with which the ancient gorge is filled, particularly near the surface, that unforeseen difficulties in securing proper foundation would not be encountered.

Mr. Wallace repeats to the board of engineers the recommendation which he had already made of the canal commission, that no temporary or tentative plan should be adopted that will interfere with the final adoption of the sea-level plan.

Mr. Quellennec, of the board of consulting engineers, at a board meeting on November 18, 1905, explained his stand in favor of a sea-level canal, stating that it was undeniable that a sea-level canal is preferable to a high-level multi-lock canal both with a view to safety and to facility of operation. He referred to his experience on the Suez Canal which has convinced him of the advantages offered by a sea-level canal. In spite of greater time and cost, he believes the sea-level canal at Panama should be constructed, but in making this statement he does not wish to be understood as saying that a lock canal is not practicable.

At the same meeting, Mr. Hunter, of the Manchester Canal, gave expression to his views on the type of canal, explaining that although as a member of the Comité Technique he favored, under the circumstances then prevailing a lock canal, he could not under the altered conditions "undertake the responsibility of joining in a recommendation to the United States for the construction of a lock canal. . . ."

Advocating the adoption of a lock-canal project, on the other hand, Mr. Noble said:

> I believe the lock canal affords quicker construction, that the wider and deeper waterways it provides would give better navigation; that the transit of ships would be quicker and that the lock canal would have even a greater capacity for traffic than the narrow waterway proposed by the sea-level canal committee.

Another advocate of the lock type of canal, Mr. Ripley, concurred in the remarks of Mr. Noble and gave as an additional reason for his position the belief that this type of canal would provide for a navigation the limit of which will not be reached in a number of years probably 40 to 75 years, so that the people of the United States will not soon be called upon to make additional expenditures for improving the canal; whereas for a sea-level canal it is quite probable that within a short time, possibly 15 or 25 years, a widening will be necessary which will cost many millions of dollars.

Mr. Parsons, also of the board of engineers, referred to the fact that a canal was to be built for all time, that it was a work of the greatest constructive magnitude ever undertaken. The plan of the canal should be of the broadest and largest possible type which we can conceive. A few years more or less in time is of no consequence. Neither is an additional cost of $50,000,000 or even $100,000,000 of importance, as there will be an adequate return. Accidents similar to those which have occurred on the Manchester and the "Soo" Canals have occurred also in the Welland and other canals. These accidents by great good fortunes have not been disasters. With locks of large size

> of the size now contemplated the results would have been more serious. It is not the danger to the ship itself that I have in mind, . . . but the danger to the canal. If at one of these big locks an accident should happen, such as has happened at other locks and as will happen here, and a ship should go plunging through and carry away the safety gates and every other mechanical device for protection, releasing the lake of water that lies behind those locks, the section of the canal between that lock and the ocean terminas would be so destroyed that it would take anywhere from one to five years to put it back in service again. The terminal port itself would be gone, the canal would be out of use, the world's traffic would be deranged and the difference in cost of the two types would be wiped out in a few seconds of time. That risk a great government can not be justified in taking.

With these views before him, and in the light of all the information then at his command, the president reached the conclusion that a canal with locks would best fulfil all requirements, and says in transmitting the board report to the Congress:

> In my judgment a lock canal as herein recommended is advisable. If the Congress directs that a sea-level canal be constructed, its direction will of course be carried out. Otherwise the canal will be built on substantially the plan outlined in the accompanying papers, such changes being made, of course, as may be found necessary, including possibly the change recommended by the Secretary of War as to the site of the dam on the Pacific side.

When the matter was before the senate committee on inter-oceanic canals, another opportunity was provided for the expression of views by experts. At these hearings, Professor Burr said that he was as strongly in favor of the sea-level canal as he ever had been.

> The more I reflect upon it, the more it seems to me that that plan is the one which the United States Government should adopt.

In discussing the Gatun dam, which is a feature of the lock-canal project as adopted, he says:

> It is proposed to build this dam by simply clearing off the surface material and then spreading the earth, suitably selected from the canal excavation, in layers, and so building it up to a height of 135 feet, making its base something like half a mile wide.[3] In my judgment, that is a dangerous experiment on a colossal scale, which this government is not justified in undertaking.

Continuing, Professor Burr states that he has no objection to earth dams under suitable conditions if properly designed and founded. Anything like a flow of water through the permeable material under the dam should be prevented. No suitable means for accomplishing this are provided in this design. He indicates measures that are ordinarily taken to check the flow of water under a dam, and instances several failures of earth dams. In speaking of the dams near LaBoca resting against Sosa Hill, the construction of which was subsequently undertaken, but owing to the yielding, unstable character of the marsh lands on which they were to rest, have been abandoned, Professor Burr says:

> The dams on the Pacific side are smaller, and the risks, perhaps, may be of less magnitude; but they are of the same character, and there is the same objection to them, in my opinion, This dam between LaBoca and the high ground opposite would be founded largely upon the most slippery kind of mud. Any one who has been there and has seen the bottom of the Rio Grande estuary exposed at low tide, I think will agree with me that it is a very lubricating material; and if you were to put a bank of earth on it, even if it were half a mile thick, I think it would be in great danger of being pushed out bodily.

In speaking of the operation of locks, he calls attention to the fact that the experience at the lock at St. Mary's Falls is not a safe guide for reaching conclusions regarding the safety of six such locks as will be required for the Panama Canal. Their lift is 50 per cent. greater,

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[3] As now contemplated, the dam is to be constructed by the hydraulic fill method.

and the dangers increase at a more rapid rate than proportional to the lift, and the dangers are magnified by the fact that the locks are to be in flights. He furthermore reaches the conclusion that the traffic capacity of the lock canal should be estimated at about 35,000,000 tons per annum instead of at 80,000,000 tons, the figure assumed by the minority.

An extended and comprehensive argument for a sea-level project was presented to the senate committee by General Davis, who, as a member of the commission of 1904, and resident on the isthmus as governor of the Canal Zone for a year, and thereupon as chairman of the board of consulting engineers, had had unusual opportunity for arriving at a mature conclusion. All that General Davis said in relation to the type of the canal before the committee should be read by those who desire to follow this matter farther. Short extracts, and a condensed statement embodying the substance of his presentation, can alone be here attempted.

> What the situation demands is well known, and the American government has declared to the world that the obstacle at Panama shall be removed. Will it be removed if we leave a hill over which the world's commerce and navies are to be hoisted? Will the world consider that we have adequately solved the problem, and will the American people be satisfied with the result if we offer them anything inferior as respects capacity, or convenience, or adaptability for enlargement, or type, to what capital did for the old world—a canal which now serves as a model, and will continue to, until we acquit ourselves of the responsibility voluntarily and eagerly assumed.

General Davis compares the Soo Canal, with its few thousand feet of channel approaches, to the great tidal harbor basins of Europe. It is more nearly analogous to these than to a great interoceanic canal on which the aggregate length of locks alone exceeds by nearly a mile the entire length of the Soo Canal. Because Lake Huron is twenty odd feet higher than Lake Erie, it was useless to hope for a channel clear of all obstructions, and American and Canadian engineers have provided the best solution possible.

> At first, locks 350 feet long sufficed. Then one 515 feet long was added. Next, the first were demolished and replaced with a lock with a chamber 800 feet long. Then the Canadians made another in their territory 900 feet long; and we are about to demolish our second lock to put in one 1,400 long. . . . The critics of the majority report admit that a canal at sea-level would have certain advantages. I think it may be said that one and all concede that if a sea-level waterway be wide and deep enough, it would be superior to any involving excavated lakes, locks and lifts; but they discard it as impracticable because of the greater cost.

The better approach to the straight line requirement by the sea-level canal is pointed out. The lock canal project shows 21 per centum more winding and tortuous navigation than the sea-level project. General Davis estimates the expense of maintenance and operation of a sea-level canal at $1,550,000 per annum, and the lock type of canal, at $2,-

150,000. The cost of the government of the Canal Zone, estimated at $100,000 is not included in these figures. Relating to dimensions, and other features of various canals, data were presented in tabular form, in part as here reproduced.

EXISTING AND PROPOSED CANALS

	Units	Panama Sea-level	Panama Lock	Suez Now	Suez Enlarged	Kiel
Total length..........	Miles	49.35	49.72	94.76	94.76	57.89
Straight portion.....	Miles	30.18	42.25	81.73	81.73	
Curved portion......	Miles	19.17	7.46	13.04	13.03	
Curved portion......	Per cent.	38.8	15.0	13.8	13.8	40.9
Depth	Feet	40	40	31.2	34.4	29.52
Least bottom width	Feet	150	200	108.26	147.63	72.17
Least bottom width in curves......... ..	Feet	150	250	131	160[4]	75.2
Least cross-section..	Sq. feet	8,160	8,160	5,813 6,025	7,741 8,144	4,444
Total curvature......	Degrees	597	637	467	467	
Curves.................	Number of	19	24	15	15	26
Locks	Number of	1	6	0	0	2
Locks, length.........	Feet	1,000	900			492
Locks, width.........	Feet	100	90			82

[4] Approximate.

The enlargement of the Suez Canal is not yet complete. The total length of the Suez Canal is 104.8 statute miles, of which about 10 miles are in lake, leaving the length of the excavated channel 94.76 miles.

The total length of the Kiel Canal is 60.89 miles, of which 3 miles are in lakes. Where two sets of figures are noted for the area of the cross-section, one applies to low, the other to high water.

General Davis shows that the proposed sea-level canal will not be dangerous, narrow or contracted, because this is not true of the Suez Canal, which is longer, narrower and shallower, and has more abrupt bends than the canal proposed by the majority of the engineers. He calls attention to the fact that in the opinion of very able engineers the cost in time will be but slightly more for the channel at ocean level, than for a canal with a summit level at 85 feet; and he says:

> It is certain that the cost in money of the simple low-level channel in which every existing and projected vessel would find convenient passage, will cost some tens of millions more than the complicated high-level structures, but the former will closely approach and ultimately result in the ideal, simple natural waterway . . . while the latter will stand for the opposite until heroic measures are resorted to and the objectionable structures are removed, for the idea of transformability is eliminated by the majority.

Col. Oswald H. Ernst, of the Engineer Corps, U. S. Army, a member of the canal commission of 1905, said in part:

> I have made a very careful review of the arguments presented on both sides, as exhibited in these two reports which you have before you—the majority and the minority reports—and I am satisfied that the United States will get a

> perfectly satisfactory canal in very much less time, and for very much less money, under the plan proposed by the minority. I believe that the canal under that plan will cost little more than half what the canal of the majority will cost, and the time will be a little more than half, and when done it will be a better canal, because it will be three times as big a canal. The volume of water in the sea-level canal is only one third what the volume of water is in the lock canal. Leave out everything in those lakes beyond the width of 1,000 feet, and everything beyond a depth of 45 feet, and you have three times the number of cubic yards of water in the lock canal that you have in the sea-level canal.

Among the earliest and best-informed advocates of the lock canal is General Henry L. Abbot, of the Corps of Engineers, U. S. Army (retired), who was a member of the Comité Technique, and was also a member of the board of consulting engineers. General Abbot has been a close, able and careful student of the hydraulic and other problems involved, and ever since the days of the Comité Technique has contributed much to the discussion thereof. In presenting his views to the board of consulting engineers, which are at too great length to be quoted in full, he says:

> The most important consideration, from an engineering point of view, in projecting a transit route, whether a railroad or a canal, is to adjust the details to the topography and natural conditions of the region to be traversed. On the Isthmus, the Chagres River is the dominating feature. . . . The deep excavation in the Culebra section is a formidable undertaking, chiefly because it will be necessary to transport the soil to long distances; but once executed, it will remain without giving occasion for anxiety in the future. The Chagres is capable of becoming a very active enemy at any future time, unless effectively tamed by good engineering methods.

General Abbot thereupon discusses the peculiarities of this river, and its relation to the several canal projects. He reaches the conclusion that the problem of the control of the Chagres is solved by the lock canal project in a manner at once vastly better and vastly more simple than by the sea-level project. He expresses his judgment, however, that the primary consideration in choosing between the two projects "should be their relative merits as routes for shipping. The elements of time and cost are secondary, but too important to be neglected." According to General Abbot, double the cost and double the time should be allowed for the completion of a sea-level canal, and when completed, the canal would be distinctly inferior to a canal with locks. In the matter of the sufficiency of the flow of Chagres River to maintain the lake above the Gatun dam, at the desired elevation, General Abbot is emphatically of the opinion that the water supply will be adequate. Based on a most

	Cubic Feet per Second
Evaporation loss, estimated	710
Leakage of gates	250
Infiltration	77
For light, power, etc.	200
Contingencies	200
Total	1,437

careful study of all existing data, on the assumption that the water surface of the lake will have an area of 110 square miles, he gives the following figures:

The water available is estimated at not less than 1,225 cubic feet per second natural flow at Gatun during the three months of lowest river stage, and to this amount there are to be added an additional volume of 1,577 cubic feet per second, resulting from a four feet allowable fluctuation of the lake surface. There are then 2,802 cubic feet per second available, of which the difference between 2,802 and 1,437, or 1,365 cubic feet per second, will be available for lockages. This amount of water, according to General Abbot, will be adequate for 26 daily transits. Should there be need for more stored water, the same can be secured by the construction of a dam at Alhajuela, where sufficient water can be impounded to increase the number of lockages by 40, though only 27 have been assumed by the minority.

It is absolutely certain that there can be no deficiency of water for any conceivable traffic demands.

Since the foregoing estimates were made it has been found that the Gatun Lake will have a surface area of about 164 square miles, instead of 110, as assumed. The lock dimensions have also been increased, as explained, and more water will be required for each transit through the canal. The estimates relating to the available water supply as above quoted therefore need revision.

And thus, in the light of the information then available, the type of the canal was fixed in 1906 by action of the Congress of the United States in substantial conformity with the recommendation of the minority of the board of engineers, and for three years the work of construction has been actively pushed.

The progress that has been made is clearly set forth in the records of work done. Measured by cubic yards of excavation it has been highly satisfactory. The graphical presentation herewith is from a recent summary published by the *Engineering News*. It appears from the figures compiled for that summary that the total excavation since the canal became the property of the United States at the close of the year 1908, amounted to 59,980,000 cubic yards, of which 53,161,000 cubic yards had been taken out of the canal prism, and 6,819,000 cubic yards were excavated from the locks and spillway sites and from other points outside of the canal proper. Of the total work, that done by steam shovels (work in the dry) amounted to 37,155,000 cubic yards, and dredges had excavated 22,825,000 cubic yards.

It has been estimated by the canal commission that the total excavation to complete the canal on the lines of the accepted project (not including the work by the French canal companies) is 142,000,000 cubic yards. According to these figures there were about 89,000,000 cubic yards yet to be removed from the canal prism on January 1, 1909.

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[illegible] rately com- [illegible] length of [illegible] own stream, [illegible] which the [illegible] method. [illegible] a practically [illegible] across the [illegible] slipping of a [illegible] the proposed [illegible] slips until [illegible] particularly near [illegible] The doubts con- [illegible] arisen from [illegible] a movement of [illegible] deposits, the ex- [illegible] information obtained [illegible] less conjectural. [illegible] the safety of the [illegible] result.

[illegible] the basis for them [illegible] underflow if suit- [illegible] the surface at the [illegible] and broken rock

[illegible] February 10, 1908, that [illegible] of the Culebra section [illegible] This fact was not known [illegible] without materially [illegible] canal may be expected to [illegible] larger deposits, so that it can not displace the earth particles with which it comes in contact in its passage under the dam. To make a convincing estimate of the volume of flow in the porous sub-surface strata under the dam is almost out of the question, because the extent, character and continuity of these strata can not be definitely ascertained, and it will be difficult, if not impossible, to determine at what point or points the water will sink from the lake above the dam into these layers. The engineers can, therefore, do no better than make unfavorable assumptions and determine the maximum water loss that may result under such hypotheses. There is no probability that this will be so great as to prove embarrassing to the project. It is to be remembered in this connection that nearly always, when a subsurface flow in a river channel has been developed by the construction of a subsurface cut-off dam, the result in water output has been disappointing. In other words, the probability is that the under-flow will be over-estimated. Nevertheless, the public seems to expect further assurance that the canal work is progressing along proper lines, particularly as it now appears probable that the cost of the lock canal will be more than double the amount named by the board of engineers in comparing the cost of the two types of canal.

In the writer's opinion, it may confidently be assumed that a safe dam can be constructed at Gatun. The situation at Gatun is, therefore, of minor importance in the further discussion of the question that has again arisen: "Would it not still be well to change the approved project and to complete the excavation to sea-level?" This question, if it be again opened, will have to be considered in the light of the views of the experts whose opinions have been herein referred to, in the light of the work already done and the progress already made; in the light of the experience on the isthmus during nearly five years of effective work, and in the light of such additional facts and conclusions as may be submitted by the engineers now about to start for the isthmus.

January 25, 1909.

TARIFF REVISION FROM THE MANUFACTURER'S STANDPOINT[1]

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MY experience as a manufacturer for more than half a century, an exporter and writer upon economic questions for about forty years, enables me to unite practise with science in demonstrating the truth of what I shall say to you.

The manufacturer's occupation, in common with most other occupations, has for its object to make money. As a social factor, his function is the elaboration of material, to meet the increasingly complex needs of a continually advancing civilization; but that and all else has to be subordinated, from a business man's point of view, to the endless task of investing smaller quantities of money and realizing larger; the difference of those two sets of quantities measuring his success or failure. He is a constructor incidentally—essentially he is a merchant. His great study is how to buy cheapest and sell dearest.

The tariff, considered as protective, is contrived and constructed with the single purpose of aiding the producer to sell dear. That aid is extended in part to production of mere raw material, but mainly to that of more elaborated articles, and the manufacturer has accordingly been always regarded as its chief beneficiary. Nor can manufacturers in general be fairly charged with ingratitude for the assistance it so graciously accords them in holding the hands of their customer while they rifle his pockets. But this grateful sentiment, though general, has never been quite universal; and the discordant voices, in the prevalent harmony, have of late grown more numerous than ever. The reasons for this—why the manufacturer is coming more and more to regard the tariff as not quite the most precious friend he has in this cold world—are, after all, very simple indeed. First, he comes to find, as his skill and facilities for production increase, that there is more profit in the greater number of sales to be had at a moderate price than in the smaller number at a high price, so that the ability to advance the price of his goods is, beyond a certain limit, no favor to him. A second and more important reason is that his interest is as much involved in buying cheap as in selling dear, and his "raw material" is always the finished product of some other producer, whose profits the tariff in-

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[1] This and the following papers on tariff revision were presented before Section I—Social and Economic Science—at the recent Baltimore meeting of the American Association for the Advancement of Science.

creases, just as it increases his, by adding to the price of the article sold. Thus the same agency that helps him at one end hinders him at the other, and the hindering is usually greater than the helping. Why? Not because the tariff rates are proportionately greater on the material he buys than on the wares he sells, for they are in most cases less; but because anything that forces him to charge a higher price for his products in order to get the same profit from the manufacture and sale of each, must at the same time diminish the number he can sell. The wise manufacturer, like other sellers, looks for "small profits and quick returns," but returns are not quick when even a small profit necessitates a high price.

There are additional reasons, worthy of consideration, why the tariff is no such aid to manufacturers in general as it was designed and is claimed to be. It is not possible to depend for success on the favor of any government, autocratic or popular, and at the same time lead as vigorous and normal a career as when independent. One eye must be kept all the time on the business, and the other eye on the seat of authority--St. Petersburg or Washington. Part of the savings must be spent in keeping friends at court, or a lobby in the national capitol; or a subsidized press. Every congressional election must bring a fresh expense—a "frying of fat," as one United States senator termed it. But besides this waste of power, the cause in which it is incurred must suffer to an incalculable extent from the corruption which often attends (and is always suspected, whether discovered or not) the enactment of legislation from which individuals may derive a profit. Any deterioration of political morality tends to lower the self-respect of every citizen, and hurts business by lowering the public credit on which it is based. There is no proof that revisions of the tariff have been undertaken for the sake of the rewards that might be secured by those in charge of them, from the "favored industries" whose fortunes they are so powerful to make or mar; and probably there have been no such strokes of legislative enterprise in our history. But it is interesting to observe that the "friends" of the tariff, in whose hands we are so often exhorted to leave the entire office of amending it, have actually made a great many more revisions, generally upward—done many times more "tariff tinkering"—than ever have the friends of the mass of the people who bear the tariff's cost. The next revision will also be of the same character—by the friends of the system.

It is dangerous to invade the citizen's natural rights. The privilege enjoyed by some producers, of having all others taxed for their profit, delightful though this privilege may be to the possessor, is not a natural right, nor can years of undisturbed possession make it so. But the right to buy wherever one wishes to buy at the least attainable cost *is* one of the natural rights. The question of liberty of purchase is the same as of liberty of any other kind. There are the same excuses for restricting it, the same motives for maintaining it. To be sure, there is something better than any liberty in an unquestioning submission to a higher guidance; greater than being our own master is unshaken loyalty to God as our master. Yet in practise, all attempts that have been made to find a ruler of a state, whose government could be in like manner better and greater than free citizens' government of themselves, have proved failures, and personal liberty remains a natural right—not because "the voice of the people is the voice of God," but only because of the imperfection of every accessible substitute. Perfect wisdom, we may readily admit, would easily guide us to purchase more wisely, and make a better selection of persons to purchase from, than is possible to our free choice; but it is absurd to look to the authors of tariff laws for such perfect wisdom, and our natural right remains. The country's defense occasionally calls upon its citizens for sacrifices of personal liberty, and may call sometimes for sacrifices of the liberty of purchase as well as other liberty. But to make the rare occasions when sacrifices are needed for defense an excsue for a perpetual infringement of this natural right—liberty of purchase—is preposterous. To maintain an oppressive tariff for such a purpose would be ridiculous, if it were not tyrannical. The only difference between this liberty and other liberty—an adventitious and not essential difference—is the facility with which the argument from patriotism may be applied against it. Yet in every such application we must see a confusion of thought, or exhibition of ignorance, unless we leave out of view the necessary reciprocity of international trade. Imported merchandise must about equal exported merchandise in value, unless there is an exceptional demand for specie in the country trading, or in some country trading with it, or unless the payment is made in service instead of merchandise in value, unless there is an exceptional demand for specie in the country trading, or in some country trading with it, or unless the payment is made in service instead of merchandise. The British, for example, always import a large excess of merchandise because they have a large credit balance abroad, from their services in ocean carriage, yielding five hundred millions annually, and even more from interest on foreign loans. Our own country, on the other hand, having "protected" its ocean merchant-marine to death, must export an excess of merchandise to pay for carriage both ways, and must also pay a heavy interest bill to foreign investors. The important point is that there is always a practical equality which our import taxation system can not disturb. Hence it follows that the so-called encouragement to foreign labor and enterprise in buying an article made abroad, is at the same time an equal encouragement to labor and enterprise at home required to produce the merchandise that is to go abroad to pay for it. It follows, also, that if we make ourselves, as is alleged, dependent on some foreign country by buying from it something that may be needed by us in warfare, we make some foreign country dependent on us in the same act, for the commodity we must send abroad to effect the purchase.

Perhaps the most important condition of prosperity, to manufacturing and all mercantile business, is "Peace among ourselves and with all nations." There can be no reasonable doubt that continually shaping our policy with a view to possible war has a tendency to provoke war, among nations as among individual citizens; while the endeavor to increase the interdependence of nations, as of citizens, is a potent agency for peace. Free trade is thus a long step on the way toward universal peace, and as such it accords with the interests of mercantile business, as with the aspirations of all who believe in the Sermon on the Mount.

The question of the true interest of the manual laborer, too important to pass without a mention, is also too wide for adequate treatment within the limits here permissible. All other considerations might be banished from the problem, when once we convince ourselves which way the interests of the toiling millions point. If their interests demand a high protective rate of import duties, we might feel justified in adopting that policy, however objectionable it appeared on other grounds. But there is no real reason for separating the interests of the manufacturing operatives from those of their employers, and every business which would draw larger profits from cheaper raw materials and greater sales of cheaper finished products, would be sure to have more to pay its laboring men. As to the many times larger number of laborers in occupations not protected, because not subject to foreign competition or because able to meet it on its own ground by exporting, it is difficult to see anything but clear gain in the reduction of tariff duties for them. The most important of such occupations is the agricultural. Free trade is clearly to the advantage of the farmer, and whatever helps him will help those he employs. Every workman, in whatever calling, must be benefited by increasing the purchasing power of his wages, and the demand for labor in general must be increased by opening new markets abroad.

Some people pretend to believe, and some others may really believe, that free trade between countries having different wage-rates per day will tend to equalize those daily rates; but that is a fancy that finds no support in the realm of fact. It might be so if a day's work were everywhere under similar conditions and equally effective in production; but that has never been the rule, and with the increase of machinery it is becoming less and less the rule. The great difference in wage-scales prevailing in different sections of our union have established themselves and grown wider in the face of complete free trade throughout; the higher wages paid in Great Britain, with lower average cost of necessaries of life, as compared with all other countries of Europe, accompany a policy of free trade, and have advanced with it;

the protective system of the republic of Mexico or the continent of Europe has had no effect in improving the condition of laborers there; and—no end of instances could be brought to show that the supposed tendency does not exist. The only way to make out that it may exist is to ignore every test by facts. Wages are high in this country, for several good reasons; but a protective policy is not among them. Yet men even so intelligent as the manufacturers who appeared before the Ways and Means Committee, joined in protesting that they could only maintain their business, in the event of lower duties, by lowering their rate of wages. Unquestionably a lower price for the product, unless accompanied by considerably larger sales, argues either a lower total profit or a reduced cost of production; but why should these manufacturers look for their saving only to the payroll? Would they have us believe they are now paying their workmen more than the competition of other employers compels them? Or is their first thought always, in case of a business loss, to take it out of their men? As has been shown, they could not if they would.

There are positive reasons, moreover, for believing that a stronger demand for the services of the laboring man would naturally follow when we put our trade and industries into a more normal condition. It would be a benefit, surely, to cease to discourage the higher grades of industry by making their raw materials dearer. Even the protective nations of Europe—Germany and France and Italy—as well as Great Britain, adopt the expedient which Alexander Hamilton emphatically recommended as an encouragement to manufacture, admission of the raw material free of duty. Such a piece of barbarous stupidity as taxing the importation of raw wool, for instance, never occurs to European nations, although they raise many sheep. Nor do they put a penalty on shoe wearing by a tax on hides, or a premium on forest waste by barring out lumber. Again, we learn from the experience of Germany that lowering the duties on food is followed not only by a reduction in the laborers' cost of living, but by an increase in the government's revenues, and by increased merchandise exports, thus conferring a triple benefit. For another instance, we see the two Australian colonies, New South Wales and Victoria, characterized until 1901 by a difference in fiscal policy, adopted some thirty years before, and we find the free-trade colony, at first in the rear, now taking the lead in amounts manufactured and in income per capita. Once more, we are reminded by a prominent member of the British Parliament that in the twenty-eight years following 1879, when the Cobden treaty with France expired and when Germany definitely adopted a protective system, exports of British merchandise not only increased, but increased by a much greater amount, than during the thirty years that preceded; thus proving that free trade encourages exports, not only when other countries reduce duties at the same time, but also when the whole world appears arrayed against it. The reason of this tendency of free trade to advance industry, as I pointed out, in an address before the International Free Trade Congress in London last summer, is "that every agency for reducing and obstructing importations must at the same time, a little less directly but precisely as powerfully, obstruct and reduce exportations."

It is altogether fallacious to treat the interest of the manual laborer as if it were something apart from that of the people as a whole—as if it were not practically identical with that of the consumer generally. Yet it seems peculiarly absurd to sunder the two in this case, because the main interest of the consumer, in cheaper and more abundant production, is one that necessarily and especially involves a great and steady increase in the demand for labor. That helps us to understand what so puzzled our great-grandfathers, the tendency of labor-saving machinery to bring prosperity instead of ruin to the working people. Free trade, now feared on exactly the same grounds as our ancestors feared labor-saving machines, will be sure to work the same way, as is proved by the last half century of English history.

A pretended connection of low-tariff legislation with panics and hard times has again and again been brought forward to befog the people's minds. It might be thought that the example seen a year and a half ago, of a business crisis occurring under the untrammeled sway of unmitigated Dingleyism, would cure any such notion. But since custom seems to devolve upon the tariff reformer the duty of accounting for all financial crises, it is worth while to say that the best explanation of that of 1907 appears to be the unnatural stimulus to protected industries given by the Dingley tariff, resulting in overproduction and a consequent glut, with which the inelastic currency system still surviving to curse our country was powerless to cope. But we must limit this degree of connection: if people are diligently enough taught to regard anything—no matter what—as the cause of panics, the appearance of that thing will produce a panic as the direct effect of the teaching. There is hardly even that connection between political economy and political boundary lines. It is everywhere conceded, probably, that a free exchange of goods is a benefit to our citizens throughout our northern territory, as far as the Canadian border. But why should there be an abrupt change across that artificial line, where conditions —except the color of bunting floating from buildings—are all the same? This reminds me of an old story of a German who lived, or thought he lived, in Pennsylvania, before the boundary was settled by Mason and Dixon. The border line, which he had believed to be just south of his house, was finally fixed a few lines north, and Hans was told that he now lived in Maryland. He replied: "I'm very glad of it, for I am told it is warmer in Maryland than in Pennsylvania."

The tariff, like national questions generally, ought to be settled on the broad ground of principle. Fundamentally illogical, it is clumsy as a means of raising revenue, incurably inequitable in its application to the business of the country, corrupt and demoralizing in the way it is made into law, in the relation it forms between the government and the citizen, and in its creation of vested rights that too soon become vested wrongs. Hence arises a natural difficulty in discussing such a subject. Tariff revision? The only suitable revision is to revise it out of existence, except upon luxuries and articles coming under internal revenue taxation. It is difficult, also, to give serious attention to a complicated scheme of what Bastiat has so happily called "negative railways"—duties whose sole object is to increase the "friction of exchange," to heap up obstacles to commerce in the place of those which railways, steamship lines and good roads are provided and constructed to remove.

Considerably more force might be given to this general discussion by taking up some individual articles, such as iron and steel, or borax, or lumber, or wool, or hides, and applying the argument to it alone. Or a particular manufacturing business might be taken, as agricultural implements, or shoes, or carpets, and the effect of protecting its raw material be individually considered. Although the general principle applies throughout, it is quite natural that its illustrations should be easier to draw, and clearer to see, in some lines than others. Particular cases have been the theme of the weeks recently spent, and pages on pages printed, in the investigation by the Ways and Means Committee of Congress. With a general impression that that committee is likely to do as little as it can, it may nevertheless be fairly complimented on the interesting body of testimony it has heard and published.

Since the problem of tariff revision, here and now, is largely one of psychotherapy—how to "minister to a mind diseased"—since the only evil in tariff reduction is a direct result of the expectation of evil from it, just as panics result from a disappearance of confidence—the Ways and Means Committee method of looking for a solution may not be so hopelessly bad, after all. It is of vital concern to escape the general panic that might follow from the conviction of many men that lower duties would play havoc with them; and it is therefore proper enough to see and hear those men, and thus ascertain how delicately cases like theirs must be treated. Individually, no doubt, minds of this type are as little significant as the separate organisms that are collectively the cause of trichinosis, or typhoid, or cholera; but, like the same weak or undeveloped organisms, their number may be enough to give them a grave importance. Among the things that were with certainty predicted of this Ways and Means inquiry was that it would not recommend or introduce any measure that would reduce the percentage of protection to the excess of labor-cost of production in the

United States over that in Europe. This certainty comes from two sources: first, the difference in a large number of cases, even of high-protected articles, is the other way. The foolish assumption that a difference in wages per day means a precisely similar difference in labor-cost of articles produced, deserves hardly the honor of a refutation; for a real index of the fact, we can not do better than note, as did Mr. Carnegie, who is probably the best living authority on the subject, the confessed profits of the U. S. Steel Corporation: $133,000,000 net in 1907, on 10,000,000 tons of steel. They thus cleared $13.50 per ton, which, deducted from the selling price, leaves a cost-price lower than can be equalled in any country in the world. Every penny of that $13.50, above the "reasonable profit" that the world's competition would allow, is obviously a gratuitous bestowal of the people's money upon the trust; but our present concern with it is as a conclusive demonstration of lower labor-costs here than in Europe. The same is true, to a less striking extent, in the case of every product which is freely exported from this country. A second reason why we know that the committee will not apply this difference-in-labor-cost criterion is found in the absurdity of the principle itself. The little boy in the story, whose sympathies, in viewing a picture of Daniel in the den of lions, were especially called out by "that poor little lion in the corner, that was not going to get any of Daniel," seems particularly absurd when we first hear of him; but he was quite a master in protectionist logic. This criterion of labor-cost shows a very nice regard for the equities among the lions who are to feed on Daniel, and no regard for the prophet himself.

It would be interesting, also, to discuss the tariff before a scientific audience, as a purely scientific question, in a scientific way. This would involve, probably, an examination of the evolution of a national policy from a community policy, showing how each development on the larger scale had been long preceded by a similar development on the smaller. The question of division of labor, among members of a tribe, was probably as hotly discussed in its day as is the question of promotion or suppression of foreign trade in this; and quite possibly the arguments then made, on the one side and on the other, were very similar to those we now hear. The reason why no record of this ancient debate remains for us is doubtless that the decision was so complete and conclusive that it passed in a short time beyond the field of controversy; and so we may hope for the question of to-day—when the present pleas for industrial independence of nations shall have gone to join the old-time pleas for industrial independence of families, just as we expect national wars and war preparations and war policies to follow into obsolescence the continual tribal wars and hostile proceedings of the past.

TARIFF REVISION FROM THE MANUFACTURER'S STANDPOINT

By H. E. MILES

RACINE, WIS.

I WRITE as a Protectionist and a Republican. I believe thoroughly in the old-fashioned principle of protection to American industries and labor, as first accepted by Hamilton and Washington.

I understand that under our constitution money can not be properly legislated out of the pocket of a private citizen by Congress except for value received. I believe that the citizen does get value received from a tariff which gives to any desirable, well-managed industry a protection tariff which measures, in the language of Mr. Taft, "substantially the permanent differential between the cost of production in foreign countries and that in the United States." If it costs 90 cents to produce an article in Germany and $1.00 in New York, the New York manufacturer must be protected by the difference in this cost or must go out of business, leaving the American market to be supplied from Germany. The other alternative, that he cut his wages and lower the standard of living to his operatives is impossible.

I believe it pays the American consumer to maintain American manufacturing industries by whatever addition to price protection so measured requires. Also that this difference should be figured with that enlightened selfishness which ordinary prudence justifies. The duty, in the above instance, might well be 20 per cent., thus giving the American producer an advantage equal to 8 per cent. and causing the foreigner to pay this much for the privilege of entering our market and enjoying the protection of our laws, for the support of the government, etc. Protection of this kind steadies the home market, stimulates manufacturing, diversifies pursuits and should bring only beneficent consequences.

During this generation, politicians, economists and others in considering this question have seemingly spent all their time and energy in the discussion of the abstract theory of protection versus free trade. They have not got down to earth. They failed adequately to consider, or at least to emphasize and apply the principle of measurement above indicated, and from this omission came the opportunity for evil, of which special interests have made full use.

With public opinions overwhelmingly for protection, and no rule of measurement, it is small wonder that infinite loss and harm have come to us as a people, economically and morally. If there is an honest rate in the present tariff I am unable to name it after two or three years of study, and if shown one I should be obliged to think it accidental. It could not have come upon careful consideration and exhaustive determination, for there has been no governmental process by which a rate could be made scientific and right. Our tariffs have been made by men almost wholly inexperienced in that work. Mr. McKinley, for instance, was the only man of previous experience among the majority members of the committee which framed the McKinley bill. The stories as to who wrote the schedules are scandalous, and, I judge, are true.

I know, for instance, that Mr. McKinley said to the head of an important industry: "Of course I do not know what rates you should have. You make them out and be fair about it." The gentleman addressed consulted others in his industry, and recommended some of his principal products for the free list because they were made more cheaply here than abroad, and were sold abroad higher than the domestic price. Mr. McKinley so recommended to his committee, but greedy men intervened and a miscalled protection was given in the bill of 65 per cent. It still bears about that rate and is still exported in large quantities at better than domestic prices.

So of the Wilson bill. Only three members of the majority upon that Ways and Means Committee, possessed previous experience and that as minority members upon the McKinley committees, where they had too great consideration for the majority even to be present when the real work was done. These three men with others wholly inexperienced made the Wilson bill. It was this so-called free trade Wilson bill that, by a wretched hocus-pocus, put Standard Oil upon the free list and gave at the same time a protective duty of 100 per cent. at an annual cost to the American people of about $40,000,000 per year. That lying "protection" was continued in the Dingley bill. When H. H. Rogers, manager of the Standard Oil Company, was asked how he got this protection from the "free trade" Wilsonites, he put his head back and laughed. There could be no better comment from his standpoint.

And from that day to this the Honorable S. E. Payne and John Dalzell have been on the committee "standing pat"—poker-playing as it were—with the people's money, playing the "game" with intent to lose, and losing in twelve years to the Oil Trust alone $360,000,000 of the people's money and to other trusts ten times more.

The free-trade Wilson bill also gave a high protection to sugar, and the sugar people offered money in large amounts for votes. The protection given them caused sugar stocks to advance ten points in forty-eight hours. Said President Cleveland of the Wilson bill—"Bought, bought, bought."

The Dingley committee had among its majority members only four men, Messrs. Dingley, Payne, Dalzell and Hopkins, a newspaper editor and three attorneys, and Mr. McMillan of the minority, with previous experience. That men so inexperienced should have hastily made a tariff for this nation was worse than a blunder—it was a crime. They only made a great blind jab at the task. They began wrong by taking classifications more than a generation old, inapplicable to their time. The committee had neither knowledge nor time to consider this important phase of the subject adequately. Consequently, we have had 30,000 lawsuits on the classifications of the appraisers, nine tenths of which might have been avoided. They put in one classification, for instance, buttons, stoves, electric fans, revolvers, nails, dress trimmings, railway cars and enameled portraits, cannon for war and crosses for churches. They were as careless as to rates. Said a member of the Ways and Means Committee in conversing with me upon this subject, "Why, when any one down in my district wants anything I get it for him, I get all I can, and that is all there is to it."

When Congress passed the Dingley bill it went into the trust-making business up to its eyes. A list which I have compiled of all the principal industrial trusts in the United States shows an absolute and complete disregard of the principle of measurement, or any other principle in the making of the schedules in which trusts are interested. A table showing the more important of these trusts was exhibited.

The tariff is supposed to be a protection to wages. This table shows that most of the trusts have tariff rates that are from one to fifteen times their total pay-rolls and yet the tariff should measure but little more than the *difference* between the American wage cost, per unit produced, and the foreign cost. In this sense these trusts have from fifteen to one thousand times a just rate. When Congress gives more than a just rate to any industry it invites, as a practical matter, those in that industry to form a trust and add to their prices as against the home consumer the difference between a fair protection and the excessive protection given.

Prohibition is not protection. An excessive tariff is usually prohibitive. It makes foreign competition impossible. The home producers by consolidation eliminate home competition and then have their 80,000,000 compatriots at their mercy. When, for instance, Congress put a duty of 45 per cent. upon goods I make, 15 per cent. being enough, it gave Congressional permit, if not a Congressional invitation, that all in my industry consolidate and add to our present domestic prices the difference between the necessary 15 per cent. and the 45 per cent. given. This is what all our trusts have done. The question whether any industry does add much or all of the tariff to its domestic prices is answered by this other question, "Can they?" If they can they do. Trusts can and trusts do.

As Mr. Carnegie has said, it may be taken for granted that the chief purpose in forming any trust is to raise prices. Industries operating under the old-fashioned principle of competition do not add tariff excesses to their prices, because they can not. In competition, and in that alone, is protection to the American consumer.

Government reports show that the Standard Oil, for instance, charges its domestic consumers 35 per cent. to 60 per cent. more for oil than it charges its foreign consumers. Domestic users pay about 40 per cent. more for files than foreign buyers of the American-made article. The foreigner gets American-made screws for about one half the price to the American consumer. Bar iron and other steel products are sold abroad at 20 per cent. to 40 per cent. less than home prices. It is a question whether ignorance is to be accepted as a congressional excuse. Said Zach Chandler, once a great senator from Michigan, "You may call me a thief, you may call me a liar, but, —— you, don't you call me a fool."

It seems impossible that our congressmen can have failed to understand that the marvelous profits our trusts make comes, in great part, not from the operation of plants, but from their manipulation of Congress itself, comes by vote of your congressman and mine, compelling you and me to make unwilling and forced contributions to trusts over and above fair compensation for their products.

It is pleasant for some to look toward Pittsburg and see the great flood of money rolling into its coffers, but look the other way. Trace the river to its sources, and you find the mighty flood dividing into millions of rivulets and at last each of them falling from a slit in a man's pocket—a slit cut by a congressman.

This situation has been brought about by the carelessness with which the American people regard their political interests, and by reliance upon the principle of competition, until recently sufficiently operative really to protect the consumer and make unnecessary scientific and exact procedure upon the part of Congress, in tariff-making.

This carelessness upon the part of Congress has now come to be practically intolerable because of the frightful excess to which many rates have been lifted. The walling in of 80,000,000 of consumers and their deliverance under an excessive rate to any who will and can "trustify" has led to the greatest exploitation of the public that has ever occurred in the history of any people. This hurt has come not only to 80,000,000 consumers, but in no less degree to the thousands of "intermediate consumers," the non-trustified competitive manufacturers who get their supplies largely from the trusts and are so overcharged as to be almost driven out of business. Steel, for instance, costs almost twice what it did when the Dingley law was enacted and the industry trustified. Those who use steel have been obliged to force their prices up against the consumer until the latter all but rebels. Consumption is limited; margins are reduced. There are 216,000 manufacturing establishments in the United States. Of these about 175,000 are still upon the competitive basis. The trusts not only charge these competitive manufacturers excessive prices for their supplies, but they sell abroad at less price, so that such of these 175,000 independents as formerly competed to advantage upon highly finished products as against European manufacturers, in neutral markets like South Africa and the Argentine are now unable successfully to compete. They are losing out in foreign trade.

Also many trusts, those in steel and hides, for instance, own subsidiary corporations that compete with the independents. These trusts charge high prices for raw material and through their subsidiary companies make the finished product at so little above the price of the raw material as to leave no margin for the independents, who must either be given relief by tariff betterment or go out of business.

An excessive tariff like the Dingley is a blow at labor. This has not been sufficiently emphasized. A reduction in the tariff to the level required by Mr. Taft's principle of measurement will give the laborers of this country three chances for a raise in wages with no chances for a decline. This raise would come (1) through a lesser cost of living, (2) by increased employment, for with a lowering of prices must come an increased demand, (3) higher daily wages. A manufacturer can pay his employers only a part of what is left in the till after the bills for materials are paid. A return to moderate but ample protection will increase the profits of competitive manufacturers. In such increased prosperity labor always shares.

And so at the behest of trusts Congress made a tariff in the name of labor which has been a blow to labor.

None has been so befooled as the farmers. A glittering nickel, as it were, has been held before the farmer's eyes as it might before a babe's, and while he has looked at the nickel his pockets have been rifled of dollars. The farmer, for instance, has been given a tariff of 15 cents per bushel on corn, a product of which he has almost exclusive control, the crop of 1908 being valued at one quarter million of dollars. Last year the government raised tariff revenue the great sum of $2.78 on imports of corn from Cuba and about $1,400.00 from the rest of the world. Likewise as to eggs. Five cents per dozen protection, $27,000 imported and $300,000,000 produced at home. Against such trifling and almost insulting gift to the farmer, he is overcharged on his implements, on his clothing, on his shoes and almost everything he buys, overcharged in all about $250,000,000 per year.

The efficiency of the American mechanic has been wretchedly minimized. The character of our laboring population was splendidly evidenced in the last campaign. Mr. Taft said to labor, "I will give you what you deserve, neither more nor less," and that statement secured for him the biggest labor vote ever given a president. So always of American labor. Upon sober thought it wants what it deserves, neither more or less.

The statements made before the Ways and Means Committee within the last few days by those who wish to bolster wretched rates imply that it takes about two American mechanics to do the work of one European, as measured in wages. Except in tariff-making we hear that it takes two Europeans to equal one American. Let us not hastily declare that high wages and other splendid considerations given American labor are an economic loss. It pays to give men a good education; it pays to feed them well, to give them meat twice a day. Porterhouse steaks are good for a workingman, if he will only work hard enough to earn them. And ours do. Manufacturers usually say that their highly-paid men are the cheapest. This statement can be made internationally also. Said J. B. Sargent, a great New England manufacturer of hardware:

> I ship abroad most successfully those of my products which carry the largest amount of the highest paid American labor. I have little success with those which carry either cheap labor or little labor.

I mention steel and other important products only as examples. The tariff is as bad generally in textiles. For instance, it lays extra-heavy burdens upon the poor man's purchases and induces the sale of shoddy and cotton as good wool. It affects chemicals, even the medicines of the sick. It reaches in all directions.

As Mr. Taft has said, a doctor will not cut off a patient's head to cure a cold. We must not destroy in seeking to correct. The tariff must be taken out of politics and put into the hands of a semi-judicial, non-partisan commission composed of men especially of the highest integrity, who shall investigate schedule by schedule and report their findings in the form of recommendations to Congress and the executive. The right to make tariffs rests wholly in Congress; a commission can only recommend, as it did in Germany. We must believe that the Congress of the United States will legislate justly and wisely if only it is fully informed. The commission must be given authority and independence only that it may be efficient as the servant of Congress.

The commission idea is not new. There are hundreds, if not thousands, of commissions, national, state and municipal. Most of the great legislative reforms of this generation were based upon the findings of commissions. There is a tremendous movement now in favor of a tariff commission. We shall have one soon, it being only a question whether this next tariff will be based upon the findings of a commission or whether this tariff will be the last one to be made after the old fashion. If it is to be made in the old way there is evidence already at hand that it will be based upon misstatements and misunderstanding. It will harm the public infinitely. It may lessen, but it will not abolish, the graft now estimated conservatively at $500,000,000 per year.

The public is thoroughly aroused and the work of reform is progressing as fast as ever any national movement of equal consequence. One of the most fortunate consequences of a justly protective tariff will be the tremendous enlargement of foreign trade. We pride ourselves upon the exportation of $1,082,000,000 of manufactured products, but 63 per cent. of these exports are crude and semi-crude; meat, petroleum, rails, billets, bar iron, lumber, cement, skins, etc. They contain 20 per cent. or less of labor. These are the very products needed by our own more numerous manufacturers at moderate prices for the employment of American operatives and the development into more highly finished products. With tariff correction, these semi-finished products will go abroad in higher forms with from two to five times more of good American labor in them. We shall become in larger and larger measure an industrial bee-hive, with our foundation world-wide and not to be shaken as heretofore by domestic panic. With this broadening of trade will come an intellectual and moral broadening and easement that will make us more truly the world power we sometimes affect to be.

TARIFF REVISION FROM THE IMPORTER'S STANDPOINT.

By FRANCIS E. HAMILTON
NEW YORK CITY

THE exchange of commodities between the inhabitants of this world began at the point of time when original savagery first felt the influences tending toward semi-barbarism, and the purely physical control of man over his fellowman began slowly to yield to less brutal methods.

From that day, many thousands of years ago, until the present time, the advancement of civilization has been accurately measured by the state of commercial development, so that we now classify nations not by the numbers of their fighting men, but rather by the magnitude of their trade.

For a long period the free exchange and barter which sent Joseph and his brethren from Arabia down to Egypt and brought the Queen of Sheba to King Solomon's gates, ruled the known world over, and the caravans of Kenghis Khan or the sailor merchants of Cleopatra bought where they could buy the cheapest and sold where they could sell the dearest—duty free—be the market at home or abroad.

As the centuries passed and the people became less nomadic, the various nations were known each to each as producers of specific articles or classes of merchandise, and the tides of commerce began to flow in more fixed channels as the years ran. The spices of the east came westward for sale to the nations of Europe and the Atlantic coasts, while the stuffs and tapestries of Germany and Italy and the weapons of Spain found markets in both England and Asia. Except when some despot, requiring the gold to fill an empty exchequer, sold the privilege to trade in particular goods and thus created a monopoly, all the merchandizing from the beginning of the Christian era down to about 1600 was free and untrammeled of duty, either import or export.

From that time on, however, it was found that in various countries and with regard to various commodities, some restriction in the market and the method of their sale was necessary or the production languished and the goods disappeared.

The first duty laid upon goods coming into this country went into operation August 1, 1789.

The necessity for providing a national revenue was the first consideration with the new congress.

Within seventy hours of the opening of the organization James Madison introduced the subject of the Tariff, in part by the following words:

> I take the liberty, Mr. Chairman, at this early stage of the business, to introduce to the committee a subject which appears to me to be of the greatest magnitude; a subject, sir, that requires our first attention and our united exertions. . . . The deficiency in cur treasury has been too notorious to make it necessary for me to animadvert upon that subject. Let us content ourselves with endeavoring to remedy the evil. To do this a national revenue must be obtained; but the system must be such a one that, while it secures the object of revenue, it shall not be oppressive to our constituents. Happy it is for us that such a system is within our power, for I apprehend that both these objects may be obtained from an impost on articles imported into the United States.
>
> In pursuing this measure, I know that two points occur for our consideration. The first respects the general regulation of commerce, which, in my opinion, ought to be as free as the policy of nations will admit. The second relates to revenue alone, and this is the point I mean more particularly to bring into the view of the committee. . . . The proposition made on this subject by Congress in 1783, having received generally the approbation of the several states of the union in one form or other, seems well calculated to become the basis of the temporary system which I wish the committee to adopt.

In closing, Mr. Madison offered a resolution declaring it to be the sense of the committee that specific duties should be levied on spirituous liquors, molasses, wines, teas, sugars, pepper, cocoa and spices, and an *ad valorem* duty upon all other articles; and also a tonnage duty upon American vessels in which merchandise was imported, and a higher rate upon foreign vessels.

From that day until this the United States has maintained a tariff. At times for revenue only, but in the main to produce a revenue and to protect home industries.

The act of August 10, 1790, was entitled "An act for laying a duty on goods, wares and merchandises imported into the United States . . . for the discharge of the debts of the United States and for the encouragement and protection of manufacturers."

It should therefore be noted that from the very inception of our government the tariff has been recognized as exercising two distinct functions; to wit, to raise a revenue and as well to protect home manufacturers.

Since the act of 1790 there have been passed by Congress thirty-three distinct tariff acts up to and including the act of 1897. Of these the McKinley act of 1890, the Wilson act of 1894 and the Dingley act of 1897, being the one now in operation, are those of most interest to the importer of the present day.

Probably no tariff act was ever placed upon the statute books that did not contain mistakes and that was not open to criticism from one source or another. The most equitable, the most liberal act must hurt some individual.

The importer who purchases his goods in other countries to sell at home, is primarily a free trader, and as such regards each per cent. of duty laid upon his particular importation as a tax upon his business. Sometimes he is so short-sighted as to consider his own particular interests as paramount, and to forget the many intricate questions involved, all of which go to the proper conduct of the commercial scheme of an entire nation.

To-day the most experienced and intelligent business men are practically agreed upon the necessity of a tariff. The unsettled question which stands between the law maker and the importer is the rate. Both are now agreed as to the justice of the principle when equitably enforced; what remains is to agree upon what is equity to the importer, to the government, to the home producer and competitor and to the consumer.

I had the honor quite recently to suggest to the ways and means committee of Congress at one of the tariff revision hearings what I regarded as a "just tariff," which should be an act so drawn as to produce the needed revenue and at the same time protect home interests. Such protection should be equally divided between the capital that establishes, the labor that produces and the public that consumes.

I am still inclined to regard the definition both concise and correct.

Mr. Taft quite recently voiced his view of the tariff principle laid down in the republican platform in the following terms:

> The measure of the tariff should be the difference between the cost of production of the article in this country and such cost abroad, and in the estimate of the cost of production abroad and in the estimate of the cost of production here there should be included among other elements what is regarded in each plan as a reasonable manufacturers' profit.

With this the importer finds no complaint, as a duty fixed along such lines would leave open to reasonable business competition all the fields wherein foreign and domestic merchandise naturally seeks a common market. What the importer does object to is the establishment of a duty which either strangles all competition, thus creating a monopoly for home products only, or a rate so high that the so-called "reasonable" manufacturer's profit becomes unreasonable, forces the consumer to pay too dearly for his goods, either foreign or domestic, and inevitably produces "trust" control in the lines affected.

Such a tariff is unjust and benefits no one but the home producer.

Under it the importer must necessarily pay a heavy bonus for the privilege of conducting his business; the consumer is compelled to pay a high price for his merchandise; and it is always unjust to labor, since the rate of duty is never used as a measure by which to regulate the wage scale. The sole beneficiary is the home producer who is enabled to realize a profit drawn from the pockets of three classes, the importers, the consumers and his own employees.

One of the best examples of a violation of the basic principle set forth by Mr. Taft is the present tariff rate upon watch movements, imported in cases or without.

Fixed in 1897 through the efforts of certain interests in this country, it has resulted in the creation of a watch "trust," producing millions of profits, even while the labor employed was often so poorly paid as to be unsettled and to have gone upon strike a number of times, and the consumer has paid for his American-made watch 20 per cent. to 30 per cent. more than the Italian, the Englishman, or even the Swiss paid for the same article purchased abroad.

That such a condition is evil, and that it should be corrected, all true lovers of their country will agree, but too often "What is every one's business is no one's," and tariff revision along this and a score of other lines equally bad can only be hoped for if the facts are placed before the Congress in convincing form.

It must ever be remembered that those who are now benefited through the protection of the tariff are on the alert to prevent any revision which will reduce their profits, whether reasonable or unreasonable, while the importer can, at the most, be only secondarily interested. He must continue business under existing conditions, although he would prefer a change, but those most interested and to whose benefit such a change would most conduce—the great mass of consumers, the people, are individuals busy with their daily affairs and unable to give the time or afford the expense which would be necessitated by any concerted effort to correct the existing wrongs.

And a great number of wrongs exist under the present act. It is somewhat of a popular fallacy that duties are levied only upon luxuries, and that the average citizen, the one who does not buy diamonds or automobiles and who has never made a trip abroad, has little or no interest in tariff questions.

That this is an error is easily proved by a glance at the act itself. There are 705 separate paragraphs, 463 of which, covering more than six thousand different articles, impose duties running as high as 60 per cent. *ad valorem*. The remaining paragraphs, 242 in number, constitute the "free list." In the minds of the general public the "free list" should contain all the necessities of life; as a matter of fact it covers less than half a dozen articles regarded as necessities, tea, coffee, needles, ice.

With all the remaining "free of duty importations" the average citizen has nothing to do. The wool which enters into the manufacture of your hat and your clothing pays a duty ranging from 4 to 12 cents per pound; the linen you wear or that is upon your bed pays 60 per cent. *ad valorem;* your stockings pay 30 per cent. *ad valorem* and the hides which are imported to make leather for your shoes pay from 15 per cent. *ad valorem* up. Gloves are taxed from $1.75 per dozen pairs to $4.75 per dozen, and jewelry pays 60 per cent. *ad valorem.*

We need to import but little food stuffs, as we are able to produce enough to supply our home necessities, but if we eat imported food we pay a tax upon it ranging from 10 per cent. to 45 per cent. *ad valorem.*

It will therefore be seen that the tariff is a subject that affects every citizen, even though he is unconscious of it, and that its revision is a matter of almost universal interest.

And because of the universality of this question it can be understood how vitally it affects all who are home producers.

The man whose business has grown up under the wing of a protective tariff will never admit that the original "infant industry" has become a lusty youth able to care for itself. He rather appears before the committee on revision and with simulated anxiety presents reasons why the protective rate should be increased, hoping doubtless by such tactics to prevent any reduction.

So general has this procedure become during the past two months while the ways and means committee have been holding tariff hearings in Washington, that lately when any one appeared before them requesting an increase in the tariff the committee would propound to him the initial query: "Are you making money in your business?"

One of the most striking examples of this pronounced selfishness on the part of the home producers was evidenced in the hearings under the paragraphs protecting oranges, lemons and olives.

A large delegation appeared from the California fruit growers, who presented to the committee among other things the statement that in the past twelve years the lemon growers had realized less than 5 per cent. net upon their investments and that unless the duty upon citrus fruits, lemons and oranges could be at least doubled, that is, made $1.60 per box instead of as at present, 80 cents, the California interest in these fruits would be destroyed.

In reply to such statement there was presented to the committee the annual report of the U. S. Government Pomologist for 1907, showing the cost per acre of maintaining the average lemon grove to be about $370.86 while the average production of one carload of fruit per acre sold at an average price during the past five years of $696.00 per car; thus making a net profit of about 90 per cent. annually; or allowing the cost of the land as given by the Californians themselves, *viz.*, $1,000 per acre, the annual returns would pay all yearly expenses and 32 per cent. upon the original investment.

No reply to this official "knock out" has been made by the citrus fruit growers, but it is not an isolated case. The rule is absolute that human nature, especially American human nature, gets all it can and keeps—if possible—all it gets. The public must look out for itself or fall under Commodore Vanderbilt's noted ban.

In the marts of trade no day passes that complaint is not voiced against the present tariff law. The mutations of eleven years have been such as to render scores of the paragraphs of that law and the duty rates imposed thereunder most inequitable and unjust. It is my belief that the so-called "good trusts" as well as the "bad trusts" have been the natural outgrowths of the tariff, and I further believe that while the good trusts should be continued and their interests safeguarded for the benefit, not of the trusts themselves, or their thousands of stockholders, but for the interests of the millions of consumers, the "bad trusts" should be shorn of the power to rob those millions of consumers, which power is now largely theirs through the protection which the present tariff gives.

To arrive at this desirable end and as well to protect his own interests is the aim of the reputable importer, and because of the reasons given above, the necessity of producing the required evidence which will prove where the evil conditions now exist, and of submitting such evidence to the Congress, devolves upon the importer.

In the parlance of the day "it is up to him" to present to those engaged in the revision of the tariff all the data required to establish the injustice of any of the present duty rates and to urge the correction of the same.

The subject is the most important which has been before the Congress in the past decade. The prosperity of the country and its people, our commercial supremacy, our national credit, all largely depend upon the result of the present tariff revision. If the new bill, which may become a law by July 1, 1909, and which surely will become a law before January 1, 1910, is just and equitable in its provisions, we may look with assurance for many years of prosperity; if on the contrary the new act retains many of the evils which have grown up under the present one, if it is so drawn as to protect favorites and to slur over or fail to eliminate the wrongs now existing within its provisions, we may anticipate commercial unrest, if not disaster, and all the attendant train of calamities.

Tariff revision, therefore, from the importer's standpoint, is of the first importance. Greater than the Canal question—for our country will go on in its magnificent career whether the Panama Canal be completed in seven years or fifteen—greater than any political issue—for experience has taught us that the people right political wrongs in the long run—greater than any questions affecting our army and navy, our insular possessions, or even the future of our ex-presidents—the question of tariff revision goes to the very vitals of national life. And this being so, the importer finds himself suddenly thrown into the lime light as the spokesman for—not alone his own interests—but as well the interests and further welfare of all the people, the great body of the nation, the consumers, and as the champion for them and to protect and ensure them in their rights for years to come, he accepts the responsibility and seeks to supply our law makers with the enormous mass of facts, and the needed evidence which they require in order to produce a finished tariff act, one that shall be grounded in "favoritism toward none and justice to all."

TARIFF REVISION FROM THE CONSUMER'S STANDPOINT

By JESSE F. ORTON
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EX-REPRESENTATIVE Charles H. Grosvenor, of Ohio, while addressing the Ways and Means Committee, December 2, on tariff revision, used this language: "It is an unfortunate reference that is constantly being made to the wants and anxieties of the consumer. . . . The prosperity of the consumer goes hand-in-hand with the prosperity of the manufacturer." We have long been accustomed to the view that the consumer's interest is a subordinate one; but now mere reference to it is "unfortunate"; perhaps it will soon be criminal, or at least an act calling for social ostracism.

The majority members of the ways and means committee did not in terms echo General Grosvenor's sentiment, that the "wants and anxieties of the consumer" should be tabooed, but most of them showed their sympathy by action throughout the hearings. Representative Boutell, of Illinois, from the very first, set out to ascertain from witnesses what effect the lowering of duties would have on what he termed "the ultimate consumer"; and this phrase soon became a standing joke with the committee. One would have thought that surely there could not be, among the constituents of these congressmen, a single person so insignificant and vulgar as this same "consumer" must be. As most of the witnesses were protected manufacturers, they easily agreed that the consumer would not be helped by any reduction of duties, that the wicked importers would take all the benefits. When witnesses thought duties should be increased, as they frequently did, they were sure that consumers would not feel the "infinitesimal" burden that would be added, if indeed any were added. There seemed to be a sort of division of labor among the committee members, and it was Mr. Boutell's task to show that the misguided consumers of the country had no need for "anxiety," that they could not be helped by removing taxes or harmed by putting taxes on. Unfortunately, a few tax-paying goats were mingled among the tax-eating sheep that appeared before the committee, and their answers were not satisfactory to Mr. Boutell; they were very sure that the consumer was hurt by taxing the things he must buy and would be relieved by reducing the taxes; but the good representative from Illinois quickly forgot the discordant notes and went on calmly stating, day after day, that the unanimous opinion of witnesses was that the consumer would not benefit, etc., and expressing a hope that, before the hearings closed, the committee might discover some schedule on which reduction of duty would profit "the ultimate consumer."

In showing up the folly of the consumer in supposing that he had an interest in the tariff revision, Mr. Boutell had an able assistant in Representative Gaines, of West Virginia. Mr. Gaines delighted in attempting to show that the duty, if it were all added to the selling price, would add very little to the cost of any particular article. For example, the duty on hides and leather meant only a few cents on a pair of shoes or a carriage top; and the duty on iron and steel meant only a trifle for each wagon. Plainly, it was his opinion that the consumer who would object to this small increase of cost was a very penurious fellow, one chronically disposed to find fault. As a rule, the committee members were careful to include in their reckoning only the added manufacturer's cost traceable to the duty. For example, they pointed to the fact that the duty on the leather in a pair of shoes is only about ten cents on the average, ignoring the profits that the wholesale and retail dealers must make on this ten cents, by which the added cost to the wearer of the shoes is made much greater.

There is at least one member of the committee who would not dignify the consumer's standpoint by the merest mention, Representative Fordney, of Michigan. The word consumer does not appear to be in his dictionary. He knows only the producer and regards as a blessing any duty whatever which prevents the importation of goods and compels their production in this country, no matter what may be the cost of producing them here. Here and there, among the majority members, there appeared a few indications of an appreciation of the rights and interests of the consumer. This was most noticeable in Representative Crumpacker, of Indiana, and Representative McCall, of Massachusetts, with an occasional gleam of light from Representative Hill, of Connecticut.

This general disparagement of the consumer's point of view did not seem to be the result of the old claim that the consumer does not pay tariff duties; but rather upon the consideration (1) that these taxes are small, (2) that the consumer derives great benefits from the tariff system, and (3) that if the taxes were removed, monopoly would prevent the consumer from getting the benefit. It seems to be generally admitted now that the consumer, and not the foreigner, pays the duty. One frank manufacturer said to the committee: "The consumer pays it and I am glad that he does."

If we were to inquire into the reasons why the representatives of the people at Washington are disposed largely to ignore the interest of the people as consumers, more than one answer might be made. To a certain extent, of course, this attitude is due to a peculiar economic belief, the acceptance of the protective theory, by which undue emphasis is placed upon the function of production at the expense of the correlative function of consumption. But protection, as a theory, certainly is not directly responsible for all the indifference to the consumer. Honest and consistent protection, assuming that there may be such, would not in every case forbid the consumer to purchase cheaply abroad; but would, before levying a tax on the importation of an article, give some consideration to the question whether it can be produced in this country with reasonable advantage. In like manner, honest protection would give to producing interests only such a duty as would enable them fairly to compete with foreign producers, not an excessive duty which will exclude the foreign article and enable manufacturers in this country to exact, by combination or otherwise, unreasonable or monopoly prices from consumers.

It can not be doubted that congress has departed very widely from honest or consistent protection. That this is the inevitable result of the system of protecting private industries is my own belief; but that it is a necessary consequence of that system conjoined with our unrepresentative scheme of government, I think no observer at Washington can fail to see. Not only do selfish private interests nominate and elect congressmen and control their course in regard to legislation, but congressmen themselves do not blush to have it known that they are personally and pecuniarily interested in the levying of certain tariff duties for which they vote as public legislators and for which they work and lobby with all the skill at their command. If we had a high and honest standard of public morals in congress, it would be much easier to get an honest tariff, and the consumer would not be plundered as he is now. Whatever may be said of the personal character of congressmen as compared with the personal character of city councilmen, I venture to say that the publicly established moral code in congress is lower than in most city councils. In nearly all city councils a member is not allowed to vote upon any contract or other question in which he is known to have a pecuniary interest; and in many cities all members of the council are absolutely forbidden to have any pecuniary interest in any contract awarded by that body. In Washington it is common gossip, that, out of the nineteen members of the ways and means committee which will frame a new tariff, various ones are pecuniarily interested in this or that schedule; that one is interested in tobacco, another in olives, a third in lumber, and so on. Some of these personal interests cropped out at the hearings. Representative Fordney stated that he was engaged in the manufacturing of lumber, and he bitterly opposed all proposals to remove the duty from that necessity in the interest of 80,000,000 consumers and the conservation of the country's forests. Ex-Representative Rhodes, of Missouri, told how he had introduced a bill in a former congress, increasing the duty on barytes, while he was personally engaged in producing this mineral.

A considerable number of congressmen appeared before the committee as attorneys representing private interests and asking for duties on various articles. If a judge should descend from the bench and address the court of which he is a member, or a coordinate court, in the interest of private suitors, we should at once cry out against the system which made such an act possible. But in congress, representatives, whose votes will be needed when the bill reaches the house, appear before the committee in behalf of private parties; and senators, who will vote on the bill when it reaches that body, appear and ask for favors to certain private industries. At the recent hearings Senator Hale, of Maine, a member of the finance committee, to which the tariff bill will be referred and one of the most influential men in the senate, appeared in behalf of a duty on starch.

When the judges who are commissioned to sit at Washington and deal impartially between tariff-burdened consumers and tariff-protected producers, not only represent selfish interests, but are themselves pecuniarily interested in their own decision, what wonder is it that the consumer's interests are ignored. So far as moral quality is concerned, Senator Burton's act in representing private interests before one of the government departments, for which he was sent to prison, was mild and harmless, as compared with the acts which are openly committed by members of congress in tariff legislation. The one has been made criminal by statute; the others have not.

I have dwelt at some length upon the methods and means by which tariff revision will have to be obtained under present conditions. The situation indicates that unless the law-making body is constrained by an insistent and powerful public opinion, consumers are not likely to get any fair measure of relief. With reference to the specific relief that ought to be granted, something may now be said.

It is generally admitted that many existing duties are much higher than the difference in the cost of producing goods here and abroad. This difference in cost, considering reasonable profit as one of the elements of cost, is a test which the people are entitled to insist upon at this time. If it could be fairly applied, consumers would escape the payment of tribute to monopoly, although they might be injured by the protection given to certain industries that are not well suited to this country. Among the schedules that should be entirely removed, according to this standard, may be noted iron and steel, lumber, coal, lead, salt, petroleum and hides. Among those which will stand marked reductions, on the basis of relative costs, are sugar, many chemicals, woolen, cotton and silk goods, glass and earthenware, machinery and implements generally. We have, in the wool-raising industry, one that should be removed from the protected list on the ground that the duty is a burdensome tax on the people, without any prospect of developing a supply at all adequate for the needs of the country.

That these changes which I have mentioned, and others of a like character, would bring great relief to the consumers of the country, the whole people, I think, can not be doubted by any one who does not ignore the ordinary laws of trade. If the ways and means committee, or congress believes that some or all of the relief intended for consumers would be absorbed by trusts and combinations, by the thwarting of the laws of trade, these law-makers should be reminded that this is a poor excuse for their failure to remove burdensome and unjust taxes, that their proper function is to find a remedy for acts in restraint of trade, not to make fear of these wrongful acts the pretext for continuing oppressive burdens on the people.

If duties were reduced in strict accordance with the test relating to cost of production, using cost figures that now obtain, it would certainly be found that in the near future further reductions could be made in accordance with the same rule. This is so on account of the extent to which present costs in almost every industry in this country are increased by the tariff duties themselves, making materials and labor more expensive than they would otherwise be. Thus reductions in one industry will make reductions possible in other industries, until finally we may get down off from the unnatural level of prices caused by the extraordinary tariff rates which we have had for several decades. I believe that when we get down to natural conditions, we shall find that there are few industries that any longer need protection from the standpoint of actual inability to compete with foreign producers in this market.

I have spoken of results that might follow honest application of the test relating to comparative costs of production; but I regard this test as at best capable of only a very rough and imperfect application. Costs vary so much for different times and places, and the difficulty of getting real facts is so great, that this test, probably the best that can be offered in theory for "honest" protection, is wholly unsatisfactory to consumers and to the general public interest. This fact, with many others, leads me to reject entirely the system of protection, as a scheme which is incapable of honest application. Even if we should grant the essential economic arguments of the protectionist, the irresistible tendency of the system toward corruption of government, toward discriminating and excessive duties and monopoly, toward the encouragement of inefficient industry, would condemn it as one of the greatest forces for evil existing in our present civilization.

A PERMANENT TARIFF BUREAU: ITS RELATION TO CONGRESS AND PROPER PROCEDURE FOR TARIFF REVISION

By SEYMOUR C. LOOMIS

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FROM the six volumes of conflicting testimony given by over six hundred witnesses, during the six weeks' session of the Ways and Means Committee, it is evident that the framing of a new tariff law is fraught with many perplexities. It is important to make it, as nearly as possible, adapted to the accomplishment of the desired end. Frequent changes are to be avoided, because they upset calculations which are at the foundation of trade. Even if the object of a tariff is agreed to and settled, that object may not be attained by the means proposed. A tariff builder always has in mind one or both of two ideas or results; first, revenue with which to run the federal government; second, protection to domestic industries. These ideas may be, and generally are, antagonistic. A schedule which produces a large revenue may not be protective, and one which is protective may produce no revenue at all. Between these extremes there are numberless conditions where the relative amounts of revenue and protection change as the duty is more or less. And when the modifications of supply and demand and the variations of cost of production are considered the situation becomes worse than kaleidoscopic. Persons may even agree as to the principle upon which a tariff law should be drafted, and yet be hopelessly apart as to its application to a given case. The essential facts relating to many industries are hidden, and, if discovered, are not easily placed and held at their true relative value. They need to be coordinated with other facts relating to other industries here as well as abroad. Iron and steel enter into and form a part of so many articles, structures and things in general, that, it is claimed, if the price of those commodities was the same here as in other countries, foreign markets, now closed, would be opened to our manufacturers who use iron and steel as their raw material. This is also claimed concerning other staples. Whether this be true or false depends upon a great number of facts, which only an expert disinterested person can discover.

For these and other obvious reasons it is apparent that a corps of men in the employment of the government under the civil service, whose permanent duty it should be to probe into, obtain and correlate these facts, would be of great public advantage and utility. A permanent commission, like the Interstate Commerce Commission, has been spoken of, which should have authority to investigate, and upon giving notice of from one to three years, to change the rate or schedule within certain limits prescribed by Congress, say from three to five per cent. A commission, however, with such powers would be unconstitutional. Article I., section 8, of the constitution provides, "The Congress shall have power to lay taxes, duties," etc. The power is given to Congress, and according to the familiar principle that no legislative body can delegate to any other person or tribunal whatever the power which was conferred upon it, such power can not be delegated to any commission. Congress must not only lay the tax and duty, but it must lay one which shall be uniform, definite and certain. It can not entrust the slightest modification or change to the discretion or judgment of any other tribunal. If a slight change in the tax can be made by a commission, then Congress can authorize it to make a great change. There is no middle ground. The entire power of laying taxes and duties is conferred on the Congress and that power can not be shifted. A commission is in no sense a representative body, and the right to lay taxes is, under our system of government, peculiarly limited to a body which is representative of the whole people. Such essentially is the Congress, to which the authority was given by the constitution.

All the benefits which would legally flow from a commission could also be had from a bureau of tariff in the Department of Commerce and Labor, and with less friction and more efficiency. Such a bureau could furnish data and memoranda with verifying witnesses, who could be examined by the Ways and Means Committee and by parties interested. In this way the whole people of the country would be represented before the committee in a substantial manner, where now they are practically unrepresented so far as the presentation of the case by witnesses and counsel is concerned. As a check upon the accuracy of the work of the bureau, parties interested should have the privilege of cross-examination, and also the right to bring before the congressional committee, which is independent of the bureau and of the department to which it belongs, experts of their own; these experts in turn to be subject to cross-examination by counsel representing the bureau of the tariff.

By such a procedure facts can be elicited upon which an orderly and scientific revision of the tariff can be made. These suggestions are not intended to unnecessarily postpone or indefinitely delay the present proposed revision of the tariff, but simply to indicate a method of procedure which should be made permanent.

JOSIAH WILLARD GIBBS AND HIS RELATION TO MODERN SCIENCE

By FIELDING H. GARRISON, M.D.

ASSISTANT LIBRARIAN, ARMY MEDICAL LIBRARY, WASHINGTON, D. C.

THE scientific papers of the late Professor Willard Gibbs, of Yale University, which have been brought together in a memorial edition by his pupil[1] and colleague, Professor Bumstead, furnish one of the most remarkable examples in existence of the value and fruitfulness of mathematical methods in scientific investigation. Originally printed in the scientific transactions of his native state, some of these papers have, by reason of the speedy exhaustion of their first imprints, been much sought after, but for many years practically inaccessible, except in French and German translations.

Gibbs was not, like Edison, Langley, Rowland, the inventor, experimenter or expert in delicate measurements, nor was he the great all-round physicist, like Maxwell, Helmholtz or Lord Kelvin. He was essentially and almost exclusively the mathematician, whose special function was not the discovery of isolated facts or new methods of experimental procedure, but the introduction of new currents of ideas; and it was the severe and rigorous form in which his ideas were cast that for a long period of time retarded their general adoption by the scientific world. If we accept Cayley's view that theoretical dynamics is in reality a branch of pure mathematics,[2] then the *opus magnum* of Gibbs, his survey of heterogeneous equilibrium, may be fairly accounted a legitimate triumph for pure mathematics.

The enormous growth of biological science in the nineteenth century has somewhat overshadowed the importance of the deductive and analytic methods which were the very life of the science of the past, and although mathematics, beginning with primitive man's attempt to count, lies at the basis of all his exact knowledge of the material world, its true function has not always been appreciated or even understood. The synthetic or Baconian method, of which we have such supreme examples in the work of Galileo and Darwin, must always appeal by its very simplicity to scientific men, since, instead of indulging in special assumptions and hypotheses, it has obtained from nature, by observation and experiment alone, facts which, as in the Darwinian theory, can be concentrated upon some special proposition to be induced with the surety of Moltke's tactical device, *Getrennt marschieren, ver-*

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[1] J. Willard Gibbs, "Scientific Papers," 2 vols., New York and London, 1906.

[2] "Report British Association for the Advancement of Science," 1884, 20.

eint schlagen. As science aims only to classify, predict and control phenomena, it has no absolute philosophic certainty except as a logical interpretation of the empirical facts of man's experience, and of the relative limitations of mathematical deduction and physical induction it has been well said that "the former breaks down on the subtlety of nature, the latter on its imperceptibility."[3] Galileo's telescope, Leeuwenhoek's microscope, Lavoisier's balance, Kirchhoff's spectroscope, are doubtless of more practical value, but certainly not of more scientific importance than formal and symbolic logic, the calculus, determinants, quaternions, vector analysis or the improved formulation of dynamics. Without induction, it is true, no new facts; but without deductive methods there could be no interpretation of these facts, nor would scientists have the means of predicting other facts which go beyond experience, or of controlling phenomena. Yet an authority so open-minded as Professor Huxley, who seems to have confused mathematical methods with the scholastic reasoning and bigotry which opposed the great cause he championed, seldom lost an opportunity to say hard things about the science "which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation."[4] In Professor Sylvester's brilliant and memorable reply to some of Huxley's after-dinner denunciations,[5] "the most eloquent of mathematicians" retorted upon his adversary that his chaffing might have been more guarded "had his speech been made before instead of after dinner,"[6] and went on to show that the maligned science employs not only imagination and invention, but observation and experiment at need. Even mathematicians, Sylvester pointed out, occasionally make discoveries, as witness Eisenstein's discovery of invariants, which was happened upon by purely physical observation "just as accidentally and unexpectedly as M. du Chaillu might meet a gorilla in the country of the Fantees."[7] The touchstone of the matter lies in the one really telling remark that Huxley made about it, viz., that mathematics will not yield correct results if applied to erroneous data.[8] The advance of modern science is largely bound up with the perfection of instruments of precision, and we have learned from the teaching of Lord Kelvin and the writings of Poincaré to recognize that mathematical

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[3] "Lectures on the Method of Science," Oxford, 1905, 12.

[4] Huxley, "Lay Sermons," New York, 1871, 168.

[5] *Ibid.*, 66.

[6] *Nature*, London, 1869–70, I., 237.

[7] *Ibid.*, 238.

[8] "Mathematics may be compared to a mill of exquisite workmanship which grinds you stuff to any degree of fineness; but, nevertheless, what you get out depends upon what you put in; and as the grandest mill in the world will not extract wheat flour from peascods, so pages of formulæ will not get a definite result out of loose data." Huxley, "Aphorisms and Reflections," London, 1907, 93.

science is itself a powerful instrument of precision, which, if applied in the right way to data of the right sort, may yield important results. Biologists like Loeb, Francis Galton, Karl Pearson, Driesch, physiologists like Helmholtz and Chauveau, psychologists like Wundt and Fechner, the leading physical chemists, van't Hoff, Arrhenius, Roozeboom, Ostwald, van der Waals, van Laar, Nernst, Le Chatellier, Bancroft, have all employed mathematics as a necessary part of their equipment, and more especially has knowledge been advanced by physicists like Maxwell, Lord Kelvin, Helmholtz, Hertz, the Curies, Stokes, J. J. Thomson and Gibbs, who have got at the more imperceptible aspects of nature by deductive methods "interlaced with physical induction and experience." In the discovery of radium by the Curies all the processes up to the use of pitchblende were inductive; after that every step taken was pure deduction, based upon the *a priori* assumption of an unknown substance. Maxwell could predict the existence of electromagnetic waves from his equations[9] at least twenty-five years before their actual demonstration by Hertz[10] and Gibbs's algebraic statement of the theorems of chemical statics was far in advance of their laboratory verification.

Ostwald, in his interesting "Biologie des Naturforschers,"[11] has divided men of science into two classes: The classicists (*Klassiker*), men like Newton, Lagrange, Gauss, Harvey, who, dealing with a limited number of ideas in their work, seek formal perfection and attain it, leaving no school of followers behind them, but only the effect of the work itself; and the romanticists (*Romantiker*) who, like Liebig, Faraday, Darwin, Maxwell, are bold explorers in unknown fields, men fertile in ideas, leaving many followers and many loose ends of unfinished work which others complete. In the logical perfection of his work and in his unusual talent for developing a theme in the most comprehensive and exhaustive manner, Gibbs was emphatically the Klassiker. But in the scientific achievement of his early manhood he showed something of the spirit of the Romantiker also. His mathematical theory of chemical equilibrium was, as we have seen, far in advance of any experimental procedure known or contemplated at the time of its publication, and, although some of his predecessors, like James Thomson, Massieu, Horstmann, had come within sight of the new land and even skirted its shores, Gibbs, with the adventurous spirit of the true pioneer, not only conquered and explored it, but systematically surveyed it, living to see part of his territory occupied by a thriving band of workers, the physical chemists. Cayley, in his report on theoretical dynamics in 1857,[12] expressed his conviction that the science of statics "does not

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[9] *Phil. Tr.*, 1865., CLV., 497–501.

[10] "Tagebl. d. Versamml. d. deutsch. Naturf. u. Aerzte 1889," Heidelberg, 1890, 144–9.

[11] *Deutsche Rev.*, 1907, XXXII., Pt. I., 16.

[12] "Report British Association for the Advancement of Science," 1857.

admit of much ulterior development." The work of Gibbs has added to it the immense field of chemical equilibrium and wherever "phases," "heterogeneous systems," "chemical and thermodynamic potentials," or "critical states" are mentioned he has left his impress upon modern scientific thought. It is not without reason then, that Ostwald has called this mathematician "the founder of chemical energetics," asserting that "he has given new form and substance to chemistry for another century at least."[13]

Josiah Willard Gibbs was born in New Haven, Conn., on February 11, 1839. His father, who was descended from Sir Henry Gibbs, of Honington, Warwickshire, was professor of sacred literature in Yale College during the years 1821–61, and was esteemed for unusual scholarship in his day. The son, like many other mathematicians, showed early aptitude for linguistic as well as for mathematical studies, and, entering Yale in 1854, was graduated in 1858, after winning many prizes and distinctions in Latin and mathematics. He began to teach mathematics and physics at Yale in 1863, having received his doctor's degree in that year. During 1866–69 he traveled in Europe, studying his chosen subjects at Paris, Berlin and Heidelberg, and hearing the lectures of Magnus, Kirchhoff and Helmholtz. In July, 1871, two years after his return, he was appointed professor of mathematical physics in Yale College, about the same time that Clerk Maxwell assumed similar duties in the Cavendish Laboratory, at Cambridge. This position Professor Gibbs held until his death, April 28, 1903. Professor Gibbs devoted his whole life to his work, the interests of his university and his pupils, and apart from the earlier years of travel and some excursions into the field of controversy, his was the quiet and uneventful career of the typical man of science. During his period of productive activity, 1873–1902, he made important contributions to the electromagnetic theory of light, multiple algebra and vector analysis, astronomy, theoretical and statistical dynamics, but his enduring fame rests chiefly upon his work in thermodynamics, the science which, in the words of his English biographer, he reduced "to its canonical form." He was a member of most of the important scientific societies of the world, was Rumford medalist of the American Academy of Arts and Sciences in 1881 and in 1901, the Royal Society, of London, conferred its highest distinction, the Copley medal, upon Professor Gibbs, as being "the first to apply the second law of thermodynamics to the exhaustive discussion of the relation between chemical, electrical and thermal energy and capacity for external work."[14]

"The history of thermodynamics," says Maxwell, "has an especial

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[13] Am 28. April 1903 verschied im 64. Lebensjahre der Schöpfer der chemischen Energetik, J. Willard Gibbs. Der allgemeinen Chemie hat er für ein Jahrhundert Form und Gehalt gegeben." *Ztschr. f. phys. Chem.*, 1903, XLIII., 760.

[14] *Nature*, London, 1901–2, LXV., 107–8.

interest as the development of a science within a short time and by a small number of men, from the condition of a vague anticipation of nature to that of a science with secure foundations, clear definitions and exact boundaries."[15] Its development falls conveniently into three stages: (1) The derivation of the two laws governing thermal transformations of energy by Carnot, Rankine, Mayer, Joule, Clausius and Kelvin. (2) The deductive application of the second law to all physico-chemical phenomena by Gibbs. (3) The application of probabilities and statistical methods to the kinetic theory of gases by Clausius, Kelvin, Maxwell and Boltzmann and the final derivation of the theorems and equations of thermodynamics by statistical induction from the average behavior of mechanical systems by Gibbs.

"It must not be thought that heat generates motion or motion heat (though in some respects this is true) but the very essence of heat or the substantial self of heat is motion and nothing else.[16] In this sentence from the *Novum Organum* it is clear that Bacon, like Descartes, Count Rumford, Sir Humphry Davy and Young, had a more or less definite notion of the dynamic nature of heat and its convertibility into work. But the exact science which treats of heat as a mode of energy begins with the publication, in 1824, of the "Réflexions sur la puissance motrice du feu" of Sadi Carnot, whom Lord Kelvin calls the "profoundest thinker in thermodynamic philosophy" in the first half of his century.[17] In this little work we have the first treatment of the heat engine as a reversible "cycle of operations," a mechanism which can be worked backward with its every action reversed; and such a system is now known everywhere as a "Carnot cycle." Carnot compared the motor power of heat to a fall of water.[18] As the power of the waterfall depends upon its height and the quantity of fluid employed, so the motor power of heat depends, not upon the nature of the working substance, but upon the quantity of heat employed and the difference in temperature between its source (the boiler) and the sink (or exhaust cylinder) to which it flows. A heat motor, then, requires a hot body and a cold body; the ideally perfect engine would be completely reversible and the efficiency of engines working between the same limits of temperature is the same. In other words, heat can not perform work except by spontaneous flow from a higher to a lower temperature. This is Carnot's principle, from which is derived

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[15] *Ibid.*, 1877–8, XVII., 257.

[16] Bacon, "Novum Organum," English translation of 1850, p. 165.

[17] Kelvin, "Popular Lectures," London, 1894, Vol. II., 460.

[18] "On peut comparer la puissance motrice de la chaleur à celle d'une chute d'eau: . . . la puissance motrice d'une chute d'eau dépend de la hauteur et de la quantité du liquide; la puissance motrice de la chaleur dépend aussi de la quantité de calorique employé, et de ce que nous appellerons le hauteur de sa chute, c'est à dire de la différence de température des corps entre lesquels se fait l'échange du calorique." Carnot, "Réflexions," 1824, 15.

the first statement of the second law of thermodynamics, that as water flows towards the sea-level, but never backwards to its source, so *heat can not flow from a colder to a warmer body.* But Carnot, like every one else in his day, still thought that heat (*calorique*), like the water in the waterfall, was an indestructible, material substance and that the quantity of heat given out by the exhaust chamber of the engine is exactly the same as that taken in at the boiler. Although his posthumous papers indicate that he corrected this view before his death, he assumed that if we could find some way to consume the heat of a given body without the necessity of conveying it to a colder body, we might create motor power without fuel or obtain work from nothing, which would be perpetual motion. As late as 1865 an authority like Rankine[19] still believed that heat is of material essence, and when in 1842–7 the labors of Robert Mayer and of Joule established the mechanical equivalent of heat and Helmholtz[20] in 1847 showed that the first law of thermodynamics, the principle of conservation of energy, is applicable to all physical phenomena, it was found difficult to reconcile this principle with Carnot's tacit assumption that heat is unchangeable and indestructible. Even a physicist like William Thomson[21] (the late Lord Kelvin) confessed himself baffled by the problem in 1849 and turned aside to establish his "absolute scale of temperature," without which further progress in the science would have been impossible; but his brother James Thomson, one of the earlier pioneers of physical chemistry, was able, by an implicit denial of Carnot's assumption, to predict and prove that the freezing point of water would be lowered by pressure (1849).[22] The difficulty was, at length, settled in 1850 by Clausius, whose memoir "On the motor power of heat," "marks," says Gibbs, "an epoch in the history of physics," for before its publication, "truth and error were in a confusing state of mixture,"[23] and "wrong answers were confidently urged by the highest authorities."

To Clausius we owe the doctrine, foreshadowed by Bacon, that the heat of a body is the rapid movement, or *vis viva,* of its molecules; the kinetic theory of gases and the molecular theory of electrolysis, since extended by Arrhenius into the doctrine of electrolytic or ionic dissociation. Clausius showed that part of the heat in a Carnot cycle is converted into available mechanical energy and consumed as work, while the rest of the heat can not be so utilized, because it exists in a completely diffused state. The perpetual motion which might be obtained from utilizing the heat of surrounding objects is impossible because such heat being completely diffused is, in Lord Kelvin's phrase, un-

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[19] Rankine, *Phil. Mag.*, 1865, 244.

[20] Helmholtz, "Ueber die Erhaltung der Kraft," Berlin, 1847.

[21] Sir W. Thomson, *Tr. Roy. Soc. Edinb.*, 1849, XVI., 543.

[22] J. Thomson, *Ibid.*, 575–80.

[23] Gibbs, *Proc. Am. Acad. Arts and Sci.*, 1888-9, n. s., XVI., 459.

available thermal energy. So the fallacious principle of the conservation of heat became merged into the doctrine of conservation of energy; the reconciliation between the first and second laws, which, like the Kantian antinomies, had seemed mutually contradictory, was effected, and Clausius reasoned that heat can not flow from a colder to a warmer body without compensation, that is, without the intervention of external forces. Meanwhile Lord Kelvin, to whom we owe our ideas and definitions of intrinsic and available energy, was able, in 1852, to shadow forth that comprehensive form of the second law afterwards stated by him as a physical law of irreversibility, according to which there is a universal tendency in nature towards irrevocable dissipation of energy.[24] From this time on progress in the science was rapid. The mathematical part of the theory was improved by the introduction of the scalar value which Rankine called the "thermodynamic function"[25] and Clausius the "entropy"[26] of a body, a variable quantity, momentary increase or decrease of which indicates (in a reversible physico-chemical transformation) whether heat is leaving or entering the body at that moment, irrespective of its temperature or previous condition. The temperature of a body, although measured by arbitrary standards, is in reality a non-measurable "intensity" or quality of the body, depending upon whether it is capable of giving up or receiving heat, *i. e.*, upon its dynamic potentiality; and, in practise, addition of heat to a body may change its physical state but does not necessarily alter its temperature; nor does a change of temperature, as Trevor has recently insisted,[27] necessarily imply absorption or development of heat; but the entropy of a body is a definite measurable "capacity," and has been compared

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[24] W. Thomson, *Phil. Mag.*, 1852, IV., 304. "Available energy is energy which we can direct into any required channel. Dissipated energy is energy which we can not lay hold of and direct at pleasure, such as the energy of the confused agitation of molecules which we call heat." Maxwell, *sub voce* "Diffusion."

[25] Rankine, *Phil. Tr.*, 1854, CXLIV., 126.

[26] Clausius, *Poggend. Ann.*, 1855, CXXV., 390.

[27] "When a mass of air is adiabatically compressed or when it expands into a vacuum, the temperature of the mass changes, but no heat is added to it. When heat is added to a block of metal, the temperature of the block rises. When heat is added to a mass of liquid water and overlying water vapor supporting a constant pressure, the temperature of the mass is not altered. Heat may be added to a mixture of potassium sulphocyanate and water in the process of forming a mixture, and the temperature fall. . . . The quantity of 'heat' added to a body in a change of its thermodynamic state is the work absorbed or absorbable by the body through direct intervention of a change of the temperature of another body. This is all that a 'quantity of heat' means. To assume it to mean a quantity of an imponderable fluid, or a quantity of the kinetic energy of hypothetical and inaccessible particles is to replace direct statement of physical facts, made with the aid of clearly defined terms, by a hypothetical interpretation of the facts." J. E. Trevor, *Jour. Phys. Chem.*, 1908, XII., 316.

by Trevor to the weight in a mechanical system. For instance, imagine a frictionless, reversible mechanical system, such as a weight suspended by a cord passing over a pulley, and let this weight by its fall to the ground do a certain amount of work, such as raising a body attached to the other end of the cord. The potential energy of the system is measured by the height of the weight above ground, and when the weight falls, the available energy of the system decreases at each point and moment of the descent, while the unavailable energy undergoes a corresponding increase point for point. On reversing the operation and raising the weight, the available energy of the system is seen to increase while the unavailable energy decreases (*i. e.*, increases in a negative direction). So, in any reversible thermodynamic system, the entropy at any moment is an index, determinant, or coefficient of the relative amount of unavailable energy it possesses. When the temperature in an isolated reversible system is constant, as in jacketed steam, the system is "isothermal" and the entropy may vary at any instant; but if a reversible system be so isolated that no heat can enter or leave the body, the temperature might vary but the entropy would be constant, and such systems, of which we have an approximation in the insulated cylinder of an engine, were called "adiabatic" by Rankine and "isentropic" by Gibbs.

There are no mathematical or ideally reversible systems in existence, although we have natural approximations to them in the motions of the heavenly bodies and in certain chemical reactions, or human approximations in reversible heat engines or reversible electric apparatus; the spontaneous processes of nature are always irreversible, proceeding irrevocably in a definite direction with no negative or reversed dissipation of energy. In spontaneous, irreversible flow of heat from a warmer to a colder body, the entropy or unavailable thermal energy of the system increases inevitably to a maximum. In other words, the entropy of a system is a criterion of its loss of efficiency or available energy during irreversible change, and it follows, in the memorable and aphoristic statement of the first and second laws by Clausius, that, while the energy of the universe is constant, its entropy (or that part of its energy which is unavailable) tends to a maximum and can never decrease:

> Die Energie der Welt ist constant,
> Die Entropie der Welt strebt einem Maximum zu.

With this important generalization, which is the motto of Gibbs's principal memoir, the first stage of thermodynamics ends. By stating the second law as irreversible increase of entropy in natural processes and by adopting some definite standard of the latter, all exact or scalar relations in thermodynamics can be treated as shown by Rankine, Clausius, and Gibbs, in a precise and definite manner.[28] But the

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[28] Maxwell and Tait originally used the term "entropy" as a synonym of

Helmholtz-Kelvin statement of the first and second laws as conservation and dissipation of energy enables us to apply these principles in the broadest and most philosophical way. Lord Kelvin extended the application of the second law to cosmic physics and, with Boltzmann, to predictions as to the ultimate thermal death of the earth. Meanwhile Clausius, Maxwell and Boltzmann began to apply the second law to the kinetic theory of gases, a phase of the subject which belongs essentially to the last stage of its development. Maxwell in particular emphasized the important point that since the heat of a body is the kinetic energy of its molecular motions, the second law is in reality not a mathematical but a statistical truth. It can not, says Maxwell, be reduced to a form as axiomatic as that of the first law, but stands upon a lower plane of probability, because it depends upon the motions of millions of molecules of which we can not get hold of a single one.[29] Could we reduce ourselves to molecular dimensions, and with the gift of molecular vision trace the movements of individual molecules, the distinction between work and heat would

Thomson's "available energy," with the statement that Clausius meant by it that part of the energy which can not be converted into work. As Gibbs pointed out, this is entirely incorrect. The entropy of a body is a definite physical property of the body itself, and can not be measured by the same unit as energy. If dQ represent the amount of heat imparted to a body at any point and T its absolute temperature at that point, Clausius has shown that dQ/T represents the infinitesimal change of entropy at that point for any given moment. The total change of entropy of any reversible chemical system in passing from an initial state a to a final state b would then be

$$\Sigma \int_a^b \frac{dQ}{T},$$

and for a reversible (Carnot) cycle the mathematical statement of the second law is the "Carnot-Clausius equation":

$$\int \left(\frac{dH}{T} \right) = 0.$$

This means that the positive and negative entropies of the system in passing from a to b and in reversing backwards from b to a must balance each other. Or as Gibbs has expressed it, "The second law requires (for a reversible cycle) that the algebraic sum of all the heat received from external bodies, divided, each portion thereof, by the absolute temperature at which it is received shall be zero." The criterion of *irreversible* processes is the "inequality of Clausius"

$$\int \left(\frac{dQ}{T} \right) < 0$$

which implies that the phenomenon will proceed irrevocably or irreversibly in a definite direction, entropy increasing or available energy dissipating to a maximum until a final state of rest or equilibrium (uniformly distributed temperature) is attained. Reversible thermodynamics deals, then, with equations; irreversible thermodynamics with inequalities, because in reversible processes the total entropy of a system remains unchanged while in irreversible processes it continually increases.

[29] Maxwell, *Nature*, London, 1877–8, XVII., 279.

vanish, and nothing would remain but the motions of material systems and the laws of mechanics. Hence the second law must either be obtained from our actual experience "with real bodies of sensible magnitude," or else derived *a posteriori*, as shown by Boltzmann, Helmholtz and Gibbs, from averages of the hypothetical motions of mechanical systems. In aid of this conception of the problem, Maxwell introduced his whimsical notion of the "sorting demon," a being endowed with molecular vision, who would be able through intelligence alone to sort or direct the molecular movements at will and so reverse the action of the second law on occasion.[30]

The second stage of thermodynamics begins in 1872–3 with August Friedrich Horstmann's application of the entropy principle to problems of chemical dissociation.[31] In October, 1873, Horstmann announced the condition for chemical equilibrium to be that of maximum entropy,[32] and in December of the same year Gibbs, in a modest footnote, stated that the condition for thermodynamic equilibrium in a chemical system at constant temperature and pressure is that the function now universally known as the thermodynamic potential should be a minimum.[33] In 1875 Lord Rayleigh stated that dissipation of energy is a sufficient if not a necessary condition for chemical change,[34] and in October, 1875, appeared the first installment of Gibbs's memoir of three hundred pages on chemical equilibrium, which, by its applications of the entropy principle to all physico-chemical or energetic phenomena, has become a true scientific classic doing for the second law what Helmholtz, in his treatise on the conservation of energy, had previously done for the first.

Gibbs began his work in thermodynamics in 1873, with two important papers on diagrams and surfaces.[35] In the first of these he made a careful and thoroughgoing study of all the diagrams that might be of use or value in thermodynamics, the best known being that upon which volume and pressure are erected to scale as coordinates, derived from the familiar Watts' indicator diagram found upon every steam engine. Of the new diagrams which Gibbs introduced, he attached most importance to the volume-entropy diagram, because it tells more about the physical properties of a working substance than about the heat employed or the work done. But the most important of Gibbs's innovations for practical engineering purposes is the temperature-

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[30] For a description of the Maxwell demon and the powers ascribed to him see Lord Kelvin's paper in *Nature*, 1879, 126.

[31] Horstmann, *Ann. d. Chem. u. Pharm.*, 1872, 8. Suppl.-Bd., 112–33.

[32] Horstmann, *Ibid.*, 1873, CLXX., 192–210.

[33] Gibbs, *Tr. Connect. Acad.*, Dec., 1873, II., foot-note to p. 393.

[34] Lord Rayleigh, *Proc. Roy. Inst.*, 1875, VII., 388.

[35] *Tr. Connect. Acad.*, 1873, II., 309–42, 382–404. Translated into French as "Diagrammes et surfaces thermodynamiques," Paris, C. Naud, 1903. Translated into German by Ostwald in 1892.

entropy diagram, which represents the efficiency of a Carnot cycle as a simple rectangular figure and is, he points out, "nothing more nor less than a geometrical representation of the second law of thermodynamics." The area of the Watts diagram represents the work done by the engine; the area of the Gibbs diagram represents the heat it has received and, either upon separate blackboards or upon "quadrant diagrams," the two taken together have proved invaluable in teaching thermodynamics to engineers. As the indicator diagram tells the engineer what he wants to know about the work done upon the piston, the efficiency of the valves and passages and the total horse power of the engine, the entropy diagram gives him the heat taken in or given out and shows directly the losses of efficiency from such heat wastes as wire-drawing of steam, incomplete expansion, etc. Professor John Perry says that the thermodynamics of heat engines is revealed by the entropy diagram "as it can be revealed in no other way," and he describes how "a man almost illiterate, innocent of algebra, can use his t, ϕ diagram of water steam or air or ammonium anhydride, obtaining in a few minutes answers to problems which the mathematical engineers of years ago spent days in solving."[36] In England the temperature-entropy diagram has been found very useful in "engine testing laboratories," and its ultimate adoption is due to the persistent crusade of Mr. Macfarlane Gray, late chief engineer of the Royal Navy, who introduced it independently in 1880 as the "theta-phi" (θ, ϕ) diagram. American engineers should not forget that this diagram was first described in scientific literature by Professor Willard Gibbs,[37] who clearly pointed out its advantages, in visualizing the second law, for teaching purposes and its use and significance when attached to heat-engines. In his second memoir[38] Gibbs extends his graphical methods to three-dimensional space, the first example of which was the volume-pressure-temperature diagram employed by James Thomson[39] in 1871. The first solid diagram described by Gibbs had for its coordinates, volume, entropy and energy and is now generally known as the "thermodynamic surface." It is a solid model or relief-map, affording a bird's-eye view of the chemico-physical changes of a system at constant temperature and pressure as it passes through the coexistent states of solid, liquid, vapor or gas. Maxwell, who had himself written learn-

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[36] *Nature*, London, 1902–3, LXVII., 604.

[37] Gibbs, *Tr. Connect. Acad.*, April, 1873, II., 317–25. The equivalent of an entropy diagram was laid down and described by the Belgian physicist M. Belpaire in 1872 (*Bull. Acad. roy. d. sc., Brux.*, 1872, 2. s., XXXIV., 520–6), but his treatment of the matter is so sketchy and slight in comparison with the exhaustive and illuminative handling of Gibbs that it seems negligible. The mere plotting of the diagram itself is nothing, for it was for years implicit in Rankine's algebraic use of the "thermodynamic function" (ϕ) as a coordinate (1854), and to this day the British unit of entropy is called a "Rank."

[38] *Tr. Connect. Acad.*, 1873, II., 382–404.

[39] J. Thomson, *Proc. Roy. Soc. Lond.*, 1871, XX., 1.

edly of diagrams, immediately recognized the importance of this paper, part of which he incorporated as a chapter in his "Theory of Heat,"[40] and, shortly before his death, he sent Gibbs a copy of a model of the thermodynamic surface constructed to scale with his own hands.[41] These solid diagrams have played a great part in the elaborate studies of the continuity of gaseous and liquid states by Van der Waals and his pupils, of which we have recently witnessed the final triumph in the liquefaction of helium.

During the years 1875–8, Gibbs published the work which is his chief title to fame, his memoir "On the Equilibrium of Heterogeneous Substances."[42] This treatise deals, as the title implies, with the statics of chemical substances which, as gases, vapors, liquids or solids, are in actual physical contact with each other, whether influenced or modified by gravity, osmosis, catalysis, capillarity or electromotive force or existing under such varied aspects as gaseous mixtures, liquid films, "solid solutions," or crystals. For the first time chemical substances are treated as continuous or contiguous "phases" of "matter in mass" acted upon, like mechanical systems, by forces having "potentials"—a new way of looking at things which has since become the definite view-point of physical chemistry. As Larmor says, "Gibbs made a clean sweep of the subject, and workers in the modern experimental science of physical chemistry have returned to it again and again to find their empirical principles forecasted in the light of pure theory, and to derive fresh inspiration for new departures."[43] Some of its theorems, as the Helmholtz doctrine of free energy,[44] Konowalow's theorem of indifferent points,[45] Curie's theory of "crystal habit,"[46] were rediscovered by later investigators in ignorance of the earlier work. Indeed the primary intention of Gibbs's memoir, to treat chemical changes as a branch of mechanics, was not, at first, clearly understood, the long deferred review in the "Fortschritte der Physik"[47] merely listing its contents. Maxwell, however, with the same cordial recognition which he had shown to Rowland, grasped its significance at once, incorporated some of its results in his memoir on "Diffusion,"[48] and in an appreciative discourse before the Cambridge Philo-

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[40] Maxwell, "Theory of Heat," London, 1902, 204–8.

[41] "Copies of this model were distributed by Maxwell evidently with a certain amount of playful mystery, for each recipient thought that he was the happy possessor of one of (at most) three. The writer knows of six at least, and possibly there are more." C. G. K. in *Nature*, 1907, LXXXV., 361.

[42] Tr. *Connect. Acad.*, 1875–8, III., 108–248; 343–594. Abstract by Gibbs in *Am. J. Sc.*, 1878, 3. s., XVI., 441–458.

[43] Larmor, "Encycl. Britan.," 10th ed., 1902, IV., 172.

[44] Helmholtz, *Sitzungsb. d. k. preuss. Akad. d. Wissensch.*, XXII.

[45] Konowalow, *Wied. Ann.*, 1881, XIV., 48.

[46] Curie, *Bull. Soc. Min.*, 1885, VIII., 145.

[47] *Fortschr. d. Physik.*, 1878, XXXIV., 198.

[48] "Encycl. Britan.," 9th ed., VII., 214–21.

sophical Society in 1876 declared that the methods of Gibbs "seemed to throw a new light upon thermodynamics." Copies of the work were consequently much prized and sought after in England about this time; but the most substantial recognition of Gibbs's work was to come from Holland, where a long line of physical chemists, van der Waals, Roozeboom, van't Hoff, Lorentz, Schreinemakers, Stortenbeker, van Laar, Hoitsema, Kamerlingh Onnes, have developed his ideas with very substantial additions to their own fame. Parallel with the work of these men and the development of the important laws of Goldberg and Waage, van't Hoff and Arrhenius, the science of physical chemistry, which DuBois Reymond called "the chemistry of the future," came into being under the leadership of Ostwald in Germany and (since 1896) of Professor Bancroft in America. With the gradual recognition of the significance of "reversible reactions"[49] and of Sainte-Claire-Deville's doctrine of chemical dissociation, the algebraic formulæ of Gibbs became slowly converted into working theories of physical chemistry. In 1892 Ostwald translated Gibbs's papers as "Thermodynamische Studien" and part of them were rendered into French in 1899 by Le Chatellier. The purely mathematical part of Gibbs's theory has been developed in extension by the labors of Duhem, Paul Sorel, Trevor, Bancroft, van der Waals, Larmor and Bryan. Roozeboom, van der Waals and Bancroft have made the widest applications of his ideas to chemistry, while their best interpretation from the dynamic or energetic point of view is that of Ostwald[50] and of Larmor.[51] Although a genial and engaging writer in his discourse on "Multiple Algebra" and his biographical sketches, the strictly scientific papers of Gibbs are not, like those of Maxwell, Boltzmann and Hertz, attractive reading. Indeed, it has been said of his memoir on equilibrium that Ostwald is one of the few people in the world who ever read every word of it, for the student is repelled, not so much by its bristling quickset of some seven hundred formulæ as by the severe and austere reasoning and a literary style that is swift in movement and (doubtless from the very nature of the subject matter) tense and dry in quality. Although endowed with the scientific imagination of a man of genius, Gibbs's strong point in demonstration was unusual quickness of intelligence

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[49] The difference between reversible and irreversible chemical processes could hardly be better indicated than in the following comparison of van't Hoff: "Kill a chicken and prepare chicken soup; it would then be very difficult to get your chicken again. This is because preparing chicken soup is not reversible. On the contrary, let water evaporate or freeze, it will be easy to reproduce the water" (*J. Phys. Chem.*, 1905, IX., 87). The distinction between reversible and irreversible reactions is thus a physico-chemical or thermodynamic conception, depending, like the operations of mechanical systems, upon the initial conditions, under which the phenomenon takes place.

[50] See Ostwald, "Lehrb. d. allg. Chemie," Leipzig, 1896, II., 2. Th., 114–5.

[51] See "Encycl. Britan.," 10th ed., XXVIII., *sub voce* Energetics.

and great capacity for the rigors of formal logic, and the rapid movement of his mind as he clears away the underbrush and covers the vast area of his new territory is wearying and even confusing to the reader. The intention of the present résumé is frankly journalistic, aiming only to emphasize such points in the Gibbsian theory as have been thrown into strongest relief by their relation to recent science. These are:

The General Equation of Thermodynamics.—In applying the laws of dynamics to thermal phenomena, Clausius had shown that if we differentiate with respect to the volume of a body, we obtain its pressure with reversed sign; if we differentiate with respect to its entropy we obtain its temperature on the thermodynamic scale; the energy of the body can then be expressed as a function of its volume and entropy, the differential coefficients with respect to the latter being the pressure (with negative sign) and the temperature. Gibbs has extended these principles to the formulation of a fundamental equation of thermodynamics, in which the new departure is taken of introducing the masses of the chemical components of a system as variables, the differential coefficients in this case being certain new conceptions which he terms the "potentials" of the substances considered. From this equation most of the principles and formulæ of thermodynamics can be deduced. It lies at the basis of the new aggregate of sciences called "energetics"[52] as well as of mathematical chemistry, in which all spontaneous changes of substance or state are regarded as more or less direct consequences of the second law. The equations of Clausius and Gibbs, although exceedingly general and difficult of application to chemistry, are exact, representing the physical facts.[53]

The Chemical Potentials.—In the fundamental equation of Gibbs we distinguish two classes of variables, of which the volume, entropy and masses of the component substances are looked upon as magnitudes or *capacities,* while the temperature, the pressure and the potentials are to be thought of as qualitative, being non-measurable, non-additive physical *intensities* of the system considered. Thus the pres-

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[52] Thoughout this paper, "energetics," thermodynamics and physical chemistry are regarded as practically identical in scope, in the original sense in which Gibbs referred to all material systems as "actually thermodynamic," or Ostwald to "das glänzendste Gebiet der heutigen Physik und Chemie, die reine Thermodynamik, oder da dieser Name viel zu eng ist, die reine Energetik."

[53] If ϵ, t, η, p and v represent the energy, temperature, entropy, pressure and volume of a homogeneous substance respectively, the equation of Clausius may be written $d\,\epsilon = t d\eta - p dv$. It is applicable to all one-component systems, such as steam in a boiler. The equation of Gibbs, which is applicable to any chemical system whatever, is written

$$d\epsilon = t d\eta - p dv + \mu_1 dm_1 + \mu_2 dm_2 \cdots + \mu_n dm_n,$$

where μ_1, μ_2 $\cdots$ denote the chemical potentials, and m_1, m_2 $\cdots$ the masses of the chemical components of the system.

sure of a substance connotes the intensity with which it tends to expand, its temperature the intensity with which it tends to part with heat, while the potential of a given chemical component represents (in Maxwell's acute interpretation) the intensity with which it tends to expel itself from the mass or compound containing it.[54] Mathematically the Gibbsian potential, which Maxwell thought "likely to become very important in the history of chemistry," has been identified by Larmor with the marginal available energy per unit mass of substance at constant temperature,[55] depending upon the percentage composition of the substance rather than its actual quantity. The chemical potentials may be regarded, not unlike the potentialities of an individual, as definite intensities which set things going, and as such their close relationship to the surface energies and surface tensions of biological science is obvious. As to the ultimate nature of the forces bound up with these potentials, whether due in the last analysis to electronic stresses or rotational stresses in the ether simply, we know little or nothing. Thermodynamic (or "energetic") doctrine rests upon the simple idea that mechanical, thermal, chemical and electric forces are different modes of energy, continually changing and passing into one another in an apparently elusive way, and is more concerned with their dynamic effects than with their actual nature.

(To be continued)

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[54] See the report of Maxwell's lecture in *Am. J. Sc.*, 1877, 3. s., XIII., 380, which is fuller than the one given in his collected writings.

[55] "Encycl. Britan.," 10th ed., XXVIII., 168.

ON A VERY PREVALENT ABUSE OF ABSTRACTION

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ABSTRACT concepts, such as elasticity, voluminousness, disconnectedness, are salient aspects of our concrete experiences which we find it useful to single out. Useful, because we are then reminded of other things that offer those same aspects; and, if the aspects carry consequences in those other things, we can return to our first things expecting those same consequences to accrue.

To be helped to anticipate consequences is always a gain, and, such being the help that abstract concepts give us, it is obvious that their use is fulfilled only when we get back again into concrete particulars by their means, bearing the consequences in our minds, and enriching our notion of the original objects therewithal.

Without abstract concepts to handle our perceptual particulars by, we are like men hopping on one foot. Using concepts along with the particulars, we become bipedal. We throw our concept forward, get a foothold on the consequence, hitch our line to this, and draw our percept up, traveling thus with a hop, skip and jump over the surface of life at a vastly rapider rate than if we merely waded through the thickness of the particulars as accident rained them down upon our heads. Animals have to do this, but men raise their heads higher and breathe freely in the upper conceptual air.

The enormous esteem professed by all philosophers for the conceptual form of consciousness is easy to understand. From Plato's time downwards it has been held to be our sole avenue to essential truth. Concepts are universal, changeless, pure; their relations are eternal; they are spiritual, while the concrete particulars which they enable us to handle are corrupted by the flesh. They are precious in themselves, then, apart from their original use, and confer new dignity upon our life.

One can find no fault with this way of feeling about concepts so long as their original function does not get swallowed up in the admiration and lost. That function is of course to enlarge mentally our momentary experiences by adding to them the consequences conceived; but unfortunately that function is not only too often forgotten by philosophers in their reasonings, but is often converted into its exact opposite, and made a means of diminishing the original experience by denying (implicitly or explicitly) all its features save the one specially abstracted to conceive it by.

This itself is a highly abstract way of stating my complaint, and it needs to be redeemed from obscurity by showing instances of what is meant. Certain particular beliefs dear to my heart have been conceived in this viciously abstract way by critics. One is the "will to believe," so-called; another is the indeterminism of certain futures; a third is the notion that truth may vary with the standpoint of the man who holds it. I believe that the perverse abuse of the abstracting function has often led critics to employ false arguments against these doctrines, and has led their readers too to false conclusions. I should like to try to save the situation, if possible, by a few counter-critical remarks.

Let me give the name of "vicious abstractionism" to a way of using concepts which may be thus described: We conceive a concrete situation by singling out some salient or important feature in it, and classing it under that; then, instead of adding to its previous characters all the positive consequences which the new way of conceiving it may bring, we proceed to use our concept privatively; we reduce the originally rich phenomenon to the naked suggestions of that name abstractly taken, treating it as a case of "nothing but" that concept, and acting as if all the other characters from out of which the concept is abstracted were expunged.[1] Abstraction, functioning in this way, becomes a means of arrest far more than a means of advance in thought. It mutilates things; it creates difficulties and finds impossibilities; and more than half the trouble that metaphysicians and logicians give themselves over the paradoxes and dialectic puzzles of the universe may, I am convinced, be traced to this relatively simple source. *The viciously privative employment of abstract characters and class-names* is, I am persuaded, the original sin of the metaphysical mind.

To proceed immediately to concrete examples, cast a glance at the belief in "free will," demolished with such specious persuasiveness in this magazine not long ago by the skilful hand of Professor Fullerton.[2] When a common man says that his will is free, what does he mean? He means that there are situations of bifurcation inside of his life in which two futures seem to him equally possible, for both have their roots equally planted in his present and his past. Either, if realized, will grow out of his previous motives, character and circumstances, and will continue uninterruptedly the pulsations of his personal life. But sometimes both at once are incompatible with physical nature, and then it seems to the naïve observer as if he made a choice between them *now,* and that the question of *which future is to*

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[1] Let not the reader confound the fallacy here described with legitimately negative inferences such as those drawn in the mood "Celarent" of the logic-books.

[2] Popular Science Monthly, Vols. 58 and 59.

be, instead of having been decided at the foundation of the world, were decided afresh at every passing moment in which fact seems livingly to grow, and possibility to turn itself towards fact.

He who takes things at their face-value here may indeed be deceived. He may far too often mistake his private ignorance of what is predetermined for a real indetermination of what is to be. Yet, however imaginary it may be, his picture of the situation offers no appearance of breach between the past and future. A train is the same train, its passengers are the same passengers, its momentum is the same momentum, no matter which way the switch which fixes its direction is placed. For the indeterminist there is at all times enough past for all the different futures in sight, and more besides, to find their reasons in it, and whichever future comes will slide out of that past as easily as the train slides by the switch. The world, in short, is just as *continuous with itself* for the believers in free will as for the rigorous determinists, only the latter are unable to believe in points of bifurcation as spots of really indifferent equilibrium or as containing shunts which there—and there only, not before—direct existing motions without altering their amount.

Were there such spots of indifference, the rigorous determinists think, the future and the past would be separated absolutely, for, *abstractly taken, the word "indifferent" suggests disconnection solely.* Whatever is indifferent is in so far forth unrelated and detached. Take the term thus strictly, and you see, they tell us, that if any spot of indifference is found upon the broad highway between the past and the future, then *no* connection of any sort whatever, no continuous momentum, no common aim or agent, can be found on both sides of the gaping wound which it makes.

Mr. Fullerton writes—the italics are mine—as follows:

> In so far as my action is free, what I have been, what I am, what I have always done or striven to do, what I most earnestly wish or resolve to do at the present moment—these things can have *no more to do with its future realization than if they had no existence.* . . . The possibility is a hideous one; and surely even the most ardent free-willist will, when he contemplates it frankly, excuse me for hoping that if I am free I am at least not very free, and that I may reasonably expect to find *some* degree of consistency in my life and actions. . . . Suppose that I have given a dollar to a blind beggar. Can *I*, if it is really an act of free will, be properly said to have given the money? Was it given because I was a man of tender heart, etc., etc.? . . . What has all this to do with acts of free-will? If they are free, they must not be conditioned by antecedent circumstances of *any* sort, by the misery of the beggar, by the pity in the heart of the passer-by. They must be causeless, not determined. They must drop from a clear sky out of the void, for just in so far as they can be accounted for, they are not free.[8]

Heaven forbid that I should get entangled here in a controversy about the rights and wrongs of the free-will question at large, for I

[8] *Loc. cit.*, Vol. 58, pp. 189, 188.

am only trying to illustrate vicious abstractionism by the conduct of some of the doctrine's assailants. The moments of bifurcation, as the indeterminist seems to himself to experience them, are moments both of direction and of continuation. But because the direction of growth is not unequivocal, and because in the "either—or" we hesitate, the determinist abstracts this little element of discontinuity from the superabundant continuities of the experience, and cancels in its behalf all the continuously connective characters with which the latter is filled. Choice, for him, means henceforward *dis*connection pure and simple, and a life of choices undetermined to advance *in any respect whatever*, must be a raving chaos, at no two moments of which could we be treated as one and the same man. If Nero were "free" at the moment of ordering his mother's murder, Mr. McTaggart[4] assures us that no one would have the right at any other moment to call him a bad man.

A polemic author ought not merely to destroy his victim. He ought to try a bit to make him feel his error—perhaps not enough to convert him, but enough to give him a bad conscience and to weaken the energy of his defense. These violent caricatures of men's serious beliefs arouse only contempt for the incapacity of their authors to see the concrete situations out of which the problems grow. To treat the negative character of one abstracted element as annulling all the positive features with which it coexists, is not the way to change any actual indeterminist's way of looking on the matter, though it may easily make a prejudiced gallery applaud.

Turn now to some criticisms of the "Will to believe," as another example of the vicious way in which abstraction is currently employed. The right to believe in things for the truth of which complete objective proof is yet lacking is defended by those who apprehend certain human situations in their concreteness. In those situations the mind has alternatives before it, so vast that the full evidence for either brand is missing, and yet so significant that simply to wait for proof, and to doubt while waiting, might often in practical respects be the same thing as weighing down the negative side. Is life worth while at all? Is there any general meaning in all this cosmic weather? Is anything being permanently bought by all this suffering? Is there perhaps a transmundane experience, something in Being corresponding to a "fourth dimension," which, if we had access to it, might patch up some of this world's *zerrissenheit* and make things look more rational than they at first appear? Is there a superhuman consciousness of which our minds are parts, and from which inspiration and help may come? Such are the questions in which the right to take sides for yes or no is affirmed by some of us, while others hold that this is methodologically inadmissible, and summon us to die professing ignorance and proclaiming the duty of every one to refuse to believe.

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[4] "Some Dogmas of Religion," p. 179.

I say nothing of the personal inconsistency of some of these critics whose printed works furnish exquisite illustrations of the will to believe, in spite of their denunciations of it as a phrase and as a recommended thing. Mr. McTaggart, whom I will once more take as an example, is sure that "reality is rational and righteous" and "destined *sub specie temporis* to become perfectly good"; and his calling this belief a result of necessary logic has surely never deceived any reader as to its real genesis in the gifted author's mind. Mankind is made on too uniform a pattern for any of us to escape successfully from acts of faith. We have a lively vision of what a certain view of the universe would mean for us. We kindle or we shudder at the thought, and our feeling runs through our whole logical nature and animates its workings. It *can't* be that, we feel, it *must* be this. It must be what it *ought* to be, and it *ought* to be this; and then we seek for every reason, good or bad, to make this which so deeply ought to be, seem objectively the probable thing. We show the arguments against it to be insufficient, so that it *may* be true; we represent its appeal to be to our whole nature's loyalty and not to any emaciated faculty of syllogistic proof. We reinforce it by remembering the enlargement of our world by music, by thinking of the promises of sunsets and the impulses from vernal woods. And the essence of the whole experience, when the individual swept through it says finally "I believe," is the intense concreteness of his vision, the individuality of the hypothesis before him, and the complexity of the various motives and perceptions that issue in his final state.

But see now how the abstractionist treats this rich and intricate vision that a certain state of things must be true. He accuses the believer of reasoning by the following syllogism:

All good desires must be fulfilled;
The desire to believe this proposition is a good desire;
Ergo, this proposition must be believed.

He substitutes this abstraction for the concrete state of mind of the believer, pins the naked absurdity of it upon him, and easily proves that any one who defends him must be the greatest fool on earth. As if any real believer ever thought in this preposterous way, or as if any defender of the legitimacy of men's concrete ways of concluding ever used the general premise "All desires must be fulfilled"! Nevertheless Mr. McTaggart solemnly and laboriously refutes the syllogism in sections 47 to 57 of his very readable book. He shows that there is no fixed rational link, no link in the dictionary, between the abstract concepts "desire," "goodness" and "reality"; and he ignores all the singular links which in the concrete case the believer feels and perceives. He says:

> When the reality of a thing is uncertain, the argument encourages us to suppose that our approval of a thing can determine its reality. And when

> this unhallowed link has once been established, retribution overtakes us. For when the reality of the thing is independently certain, we [then] have to admit that the reality of the thing should determine our approval of that thing. I find it difficult to imagine a more degraded position.

Mr. McTaggart ends his chapter with the heroic words:

> For those who do not pray, there remains the resolve that, so far as their strength may permit, neither the pains of death nor the pains of life shall drive them to any comfort in that which they hold to be false, or drive them from any comfort [discomfort?] in that which they hold to be true.

How can so ingenious-minded a writer fail to see how far over the heads of the enemy all his arrows pass? When Mr. McTaggart himself believes that the universe is run by the dialectic energy of the absolute idea, his insistent desire to have a world of that sort is felt by him to be no chance example of desire in general, but an altogether peculiar insight-giving passion to which, in this if in no other instance, he would be stupid not to yield. He obeys its concrete singularity, not the bare abstract feature in it of being a "desire." His situation is as particular as that of an actress who resolves that it is best for her to marry and leave the stage, of a priest who becomes secular, of a politician who abandons public life. What sensible man would seek to refute the concrete decisions of such persons by tracing them to abstract premises, such as that "all actresses must marry," "all clergymen must be laymen," "all politicians should resign their posts"? Yet this type of refutation, absolutely unavailing though it be for purposes of conversion, is spread by Mr. McTaggart through many pages of his book. For the aboundingness of our real reasons he substitutes one narrow point. For men's real probabilities he gives an abstraction which no man is tempted to believe.

The abstraction in my next example is less simple, but is quite as flimsy as a weapon of attack. Empiricists think that truth in general is distilled from single men's ideas; and the so-called pragmatists "go them one better" by trying to define what it consists in when it comes. It consists in such a working, I have elsewhere said, on the part of the ideas, as may bring the man into satisfactory relations with objects to which these latter point. The working is of course a concrete working in the actual experience of human beings, among their ideas, feelings, perceptions, beliefs and acts, as well as among the physical things of their environment, and the relations must be understood as being possible as well as actual. In the chapter on truth of my recent book called "Pragmatism"[5] I have myself taken considerable pains to defend this view. Strange have been some of the misconceptions of it by its enemies, and many have these latter been. Among the most formidable-sounding onslaughts on the attempt to introduce some concreteness into our notion of what the truth of an idea may mean,

[5] Longmans, Green & Co., 1908.

is one that has been raised in many quarters to the effect that to make truth grow in any way out of human opinion is but to reproduce that protagorean doctrine that the individual man is "the measure of all things," which Plato in his immortal dialogue, the Thæatetus, laid away so comfortably in its grave two thousand years ago. The two cleverest brandishers of this objection to make truth concrete, Professors Rickert and Münsterberg, write in German, and "Relativismus" is the name they give to the heresy which they endeavor to uproot.

The first step in their campaign against "Relativismus" is entirely in the air. They accuse relativists—and we pragmatists are typical relativists—of being debarred by their self-adopted principles, not only from the privilege which rationalist philosophers enjoy, of believing that these principles of their own are truth impersonal and absolute, but even of framing the abstract notion of such a truth, in the pragmatic sense of an ideal opinion in which all men might agree, and which no man should ever wish to change. Both charges fall wide of their mark. I myself, as a pragmatist, believe in my own account of truth as firmly as any rationalist can possibly believe in his. And I believe in it for the very reason that I *have* the idea of truth which my learned adversaries contend that no pragmatist can frame. I expect, namely, that the more fully men discuss and test my account, the more they will agree that it *fits,* and the less will they desire a change. I may of course be premature in this confidence, and the glory of being truth final and absolute may fall upon some later revision and correction of my scheme, which scheme will then be judged untrue in just the measure in which it departs from that finally satisfactory formulation. To admit, as we pragmatists do, that we are liable to correction (even though we may not expect it) *involves* the use on our part of an ideal standard. Rationalists themselves are, as modest individuals, sceptical enough to admit the abstract possibility of their own present opinions being corrigible and revisable to some degree, so that the fact that the mere *notion* of an absolute standard should seem to them so important a thing to claim for themselves and to deny to us is not easy to explain. If, along with the notion of the standard, they could also claim its exclusive warrant for their own fulminations now, it would be important to them indeed. But absolutists like Rickert freely admit the sterility of the notion, even in their own hands. Truth is what we *ought* to believe, they say, even though no man ever did or shall believe it, and even though we have no way of getting at it save by the usual empirical processes of testing our opinions by one another and by facts. Pragmatically, then, this part of the dispute is idle. No relativist who ever actually walked the earth[6] has denied the constitutive character in his own thinking of the notion of absolute truth. What is challenged by relativists is the pretence on any one's part to have found for certain at any given moment what the shape of that truth is. Since the better absolutists agree in this, admitting that the proposition "There *is* absolute truth" is the only absolute truth of which we can be sure,[7] further debate is practically unimportant, so we may pass to their next charge.

It is in this charge that the vicious abstractionism becomes most apparent. The anti-pragmatist, in postulating absolute truth, refuses to give any account of what the words may mean. For him they form a self-explanatory term. The pragmatist, on the contrary, articulately defines their meaning. Truth absolute, he says, means an ideal set of formulations towards which all opinions may in the long run of experience be expected to converge. In this definition of absolute truth he not only postulates that there is a tendency to such convergence of opinions, but he postulates the other factors of his definition equally, borrowing them by anticipation from the true conclusions expected to be reached. He postulates the existence of opinions, he postulates the experience that will sift them, and the consistency which that experience will show. He justifies himself in these assumptions by saying that human opinion has already reached a pretty stable equilibrium regarding them, and that if its future development fails to alter them, the definition itself, with all its terms included, will be part of the very absolute truth which it defines. The hypothesis will, in short, have worked successfully all round the circle and proved self-corroborative, and the circle will be closed.

The anti-pragmatist, however, immediately falls foul of the word "opinion" here, abstracts it from the universe of life, and uses it as a bare dictionary-substantive, to deny the rest of the assumptions with which it coexists. The dictionary says that an opinion is "what some one thinks or believes." This leaves every one's opinion free to be autogenous, or unrelated either to what any one else may think, or to what the truth may be. Therefore, continue our abstractionists, we must conceive it *as essentially thus unrelated,* so that even were a billion men to sport the same opinion, and only one man to differ, we could admit no collateral circumstances which might presumptively make it more probable that he, not they, should be wrong. Truth, they say, follows not the counting of noses, nor is it only another name for a

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[6] Of course the bugaboo creature called "the sceptic" in the logic-books, who dogmatically makes the statement that no statement, not even the one he now makes, is true, is a mere mechanical toy-target for the rationalist shooting gallery—hit him and he turns a summersault—yet he is the only sort of relativist whom my colleagues appear able to imagine to exist.

[7] Compare Rickert's "Gegenstand der Erkentniss," pp. 137, 138. Münsterberg's version of this first truth is that "Es gibt eine Welt"—see his "Philosophie der Werte," pp. 38 and 74. And, after all, both these philosophers confess in the end that the primal truth of which they consider our supposed denial so irrational is not properly an insight at all but a dogma adopted by the will which any one who turns his back on duty may disregard!

majority vote. It is a relation, that antedates experience, between our opinions and an independent something which the pragmatist account ignores, a relation which, though the opinions of individuals should to all eternity deny it, would still remain to qualify them as false. To talk of opinions without referring to this independent something, the anti-pragmatist assures us, is to play Hamlet with Hamlet's part left out.

But when the pragmatist speaks of opinions, does he mean any such insulated and unmotived abstractions as are here supposed? Of course not, he means men's opinions in the flesh, as they have really formed themselves, opinions surrounded by their causes and the influences they obey and exert, and along with the whole environment of social communication of which they are a part. The "experience" which the pragmatic definition postulates *is* the independent something which the anti-pragmatist accuses him of ignoring. Already have men grown unanimous in the opinion that such experience is "of" an independent reality, the existence of which all opinions must acknowledge, in order to be true. Already do they agree that in the long run it is useless to resist experience's pressure; that the more of it a man has, the better position he stands in, in respect of truth; that some men, having had more experience, are therefore better authorities than others; that some are also wiser by nature and better able to interpret the experience they have had; that it is the part of wisdom to compare notes, to discuss, and to follow the opinion of our betters; and that the more systematically and thoroughly the comparison and weighing of opinions is pursued, the truer the opinions that survive are likely to be. *When the pragmatist talks of opinions, it is opinions as they thus concretely and livingly and interactingly and correlatively exist that he has in mind;* and when the anti-pragmatist tries to floor him because the word opinion can also be taken abstractly and as if it had no environment, he simply ignores the soil out of which the whole discussion grows. His weapons cut the air and strike no blow. No one gets wounded in the war against caricatures of belief and skeletons of opinion of which the German onslaughts upon "Relativismus" consist. Refuse to use the word opinion abstractly, keep it in its real environment, and the withers of pragmatism remain unwrung.

That men do exist who are "opinionated," in the sense that their opinions are self-willed, is unfortunately a fact that must be admitted, no matter what one's notion of truth in general may be. But that this fact makes it impossible for truth to form itself authentically out of the life of "opinion," is what no critic has yet proved. Truth may well consist of certain opinions, and does indeed consist of nothing but opinions, though not every opinion need be true. No pragmatist needs to dogmatize about the consensus of opinion in the future being right—he need only *postulate* that it will probably contain more of truth than any one's opinion now.

THE CLOSING OF A FAMOUS ASTRONOMICAL PROBLEM

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THERE is perhaps no more striking illustration of the power of scientific method than that relating to the discovery of Neptune in 1846. The planet Uranus, until then the outermost known member of our solar system, refused to follow the path computed for it by mathematical astronomers. With the progress of time the discrepancies between its predicted and observed positions grew constantly larger until, in the early eighteen-forties, the discordance amounted to fully 75 seconds of arc. This is a small angle—not more than one twenty-fifth the angular diameter of our moon—yet a very large angle to refined astronomy, for a discrepancy of two seconds would have been detected with ease. The opinion gradually developed that Uranus was drawn from its natural course by the attractions of an undiscovered planet still farther from the sun than itself. Adams in 1843 and Le Verrier in 1845, independently, and each without knowledge of the other's plans, attacked the then extremely difficult problem of determining the approximate orbit, mass and position of an undiscovered body whose attractions should produce the perturbations observed. Regrettable and avoidable delays occurred in searching for the planet after Adams's results were communicated to the astronomer royal, in October, 1845. Le Verrier's results were communicated to the Berlin Observatory in September, 1846, with the request that a search be made. The disturbing planet, later named Neptune, was found on the first evening that it was looked for, less than one degree of arc from the position assigned by Le Verrier. If an energetic search had been made in England the year before, the planet would have been discovered within two degrees of the position assigned by Adams.

The above résumé of this unsurpassed achievement of the human mind forms a natural prelude to the present article, as it was the immediate forerunner of another problem, famous for half a century, which has now been brought to a satisfactory conclusion.

The determination of the orbit of the planet Mercury gave great difficulty to its investigators, principally from two causes:

1. Being the innermost known planet in our system, remaining always near the sun, and usually lost to view in the sun's glare, fairly

accurate observations of its positions could be secured only when the planet was near its greatest angular distances from the sun and on the rare occasions when the planet passed between us and the sun's disk. Consequently, observations of the highest accuracy were few in number; and,

2. There were large discrepancies between Mercury's predicted and observed positions, certainly not due to the attractions of any known members of our solar system.

Le Verrier, of Neptunian fame, undertook a systematic investigation of Mercury's orbit, making use of all available observations. His results were derived and published in 1859. His work established that there were peculiarities in the planet's orbital motion which could not be due to the attractions of known masses of matter. Chief among the peculiarities was a slow rotation of the orbit itself. It is best described as a forward motion of the orbit's perihelion amounting to 38 seconds of arc per century.

Le Verrier announced that the outstanding differences between prediction and observation could be produced and explained by the disturbing attractions of an undiscovered planet closer to the sun than Mercury and revolving around the sun in an orbit lying nearly in the plane of Mercury's orbit. The mass of (the quantity of matter in) the hypothetical planet would depend upon its distance from Mercury: if half way between Mercury and the sun, its mass would be two thirds that of Mercury; if further from Mercury, the necessary mass would be greater; if nearer, smaller. A group or "ring" of small planets, instead of one large planet, would serve equally well, provided the total mass of the planetoids were of the same order of magnitude. Le Verrier did not say that such an undiscovered planet or ring of planetoids did exist, but simply that it would account for the observed anomalies. The accuracy of his computations, published in detail, could not be questioned. The recognition of his masterly skill, and the memory of his entirely similar discovery of Neptune, assisted in convincing astronomers quite generally that a planet or group of planets existed. The discovery of the disturbing mass became at once a noted problem.

A body traveling around the sun in a circular orbit whose radius is only one half Mercury's average solar distance would never be more than 12° from the sun as viewed by terrestrial observers. A search for it by ordinary methods would accordingly be fruitless. A body large enough to shine brilliantly on a dark-sky background would be hopelessly lost in the bright sky near the sun. Mercury itself, though running out between 20° and 30° from the sun every few weeks, is seldom seen by any save astronomers; and they know where to look for it in the twilight sky.

Two special methods of discovery were applicable: (1) To detect the planet projected upon the sun's disk when its orbital motion carried it between us and the sun; (2) to search for it when the sky background was darkened at the time of a total solar eclipse.

Needless to say, a crop of discoverers by the first method grew up without delay. The observer of greatest note was Lescarbault, a rural physician of France. Immediately following the publication of Le Verrier's conclusions, Lescarbault announced that he had observed the transit of an unknown planet across the sun's disk several months earlier. Le Verrier journeyed to Lescarbault's home, investigated all the circumstances of the observation, weighed the evidence and concluded that a real planet had been seen. In fact, so convinced of its reality were many scientific men that the name Vulcan was given to it. Older and later reported observations of the same character, to the number of twenty, were collected by Le Verrier, and those which seemed to be in harmony with each other were made the basis of an orbit. Vulcan was found to be about one third Mercury's distance from the sun, revolving once around the sun in between nineteen and twenty days. In some of the text-books on astronomy appearing in the sixties and seventies, Vulcan was assigned a place in the solar system as conspicuous and as secure as that of Mercury itself.

Now it is probable that every one of the twenty observations referred to was erroneous, though made in good faith. In essentially every case the observer was inexperienced, and used a telescope of insufficient power, or one unprovided with measuring apparatus suitable for determining whether or not the subject observed was in motion across the sun's disk. Even the observation of Lescarbault was in doubt when it later transpired that a Brazilian observer of considerable professional experience was at the same hour studying the region of the sun in question and saw only uniform normal solar surface. The situation was not without its humorous side. For example, a Mississippi Valley weather prophet who saw Vulcan crossing the sun's disk, said it was about "as large as a new [*sic*] silver half dollar"! Many of the observations no doubt referred to small sun spots which, with small telescopes, would look round.

Vulcan was searched for by visual observers at the principal eclipses of the sixties, seventies and eighties. Two noted astronomers at the eclipse of 1878, Watson and Swift, believed that they saw two new planets near the sun. However, the two seen by Watson did not agree with those seen by Swift, and still other astronomers at the same eclipse saw no strange bodies in the same regions. As the assigned locations depended upon the hasty readings of graduated circles, in which one can so easily make errors, in the press and excitement of eclipse conditions, the astronomical world quickly, and no doubt correctly, concluded that the objects seen were well-known neighboring stars.

The perfecting of dry-plate photography gave renewed interest to the search for Vulcan, both when passing over the solar surface and at times of eclipse. Although the sun has been photographed almost daily during the past twenty years, at one observatory or another, no experienced observer has seriously claimed that his plates recorded an unknown planet crossing the sun. Neither were eclipse searches more successful: the well-known bright stars lying nearly in the direction of the sun were photographed, but no strange bodies. Curiously enough, the optical principles governing the efficiency of cameras in this search were overlooked for many years, and faint objects near the sun—say stars fainter than the fourth magnitude—were not observable, because their images, though formed on the photographic plates, were overwhelmed and buried from sight in the general darkening of the photograph by the bright-sky background. It was not until 1900 that the elements of the problem of photographing faint bodies near the sun were comprehended. While preparing for the eclipse of that year, three astronomers, Professor W. H. Pickering, of Harvard College Observatory, and Messrs. Perrine and Campbell, of the Lick Observatory, independently arrived at the same simple conclusion that the focal lengths of the intramercurial-search cameras should be relatively long, in order to reduce the intensity of the sky exposure on the plates without reducing the intensity of the star images, and thus let the latter be seen on the negative. The principles involved are so simple as hardly to call for elucidation.

Let the two cameras have lenses of equal aperture, say 3 inches, of equal transparency and capable of covering equal *angular* fields of view, say a circle 10 degrees in diameter. Let one be of short focus, 21 inches, and the other of long focus, 135 inches. The powers of the two lenses to record stellar points on the sensitive plates in focus, under good atmospheric conditions, are not very unequal, for the two lenses collect equal quantities of light and condense the light into images of very nearly the same size. Both collect the same quantity of sky light, but the longer-focus camera spreads it (more thinly) over an area $(135)^2/(21)^2 = 41$ times the greater. It is evident that faint-star images hopelessly lost to view on the sky-blackened small plate may be seen with ease on the nearly clear glass of the large plate. We may safely say that the large plate will show images of stars 3 or $3\frac{1}{2}$ magnitudes fainter than the small plate. The same advantage exists for small intramercurial planets as for stars, provided the exposures do not exceed two or three minutes in length, as they seldom do at eclipses. In longer exposures on intramercurial planetoids the advantage would usually be lost, as their rapid (and unknown) motions would cause their images on the plate to move, slowly with short-focus and rapidly with long-focus cameras, thus drawing them out into trails. With the longer instrument here described, an eight-minute exposure would in general be no more effective than one of four minutes. The most successful instrument for the search in question must compromise between the advantage of long focus in reducing sky density, and the disadvantage of long focus in producing long trails. Shorter exposures, giving shorter trails, may be provided by increasing the diameter of the lens, but this in turn means greater unavoidable optical aberrations in the outer areas of the region photographed, which is a reduction in efficiency. In this as in all instruments, extensive experience and good judgment must combine to decide upon the best compromise-proportions.

Professor Pickering, of Harvard, and Mr. Abbot, of the Smithsonian Institution, used such cameras at the total solar eclipse of 1900. The latter observer was favored with good conditions, in North Carolina, and he secured one photograph of a considerable area surrounding the eclipsed sun. Quite a number of the stars known to exist in this region were photographed; but in the absence of a duplicate photograph of the same region, he could not decide whether certain apparent images on the plate were due to unknown planets, or were defects such as always exist in photographic films.

At the eclipse of 1901, in Sumatra, Mr. Abbot, of the Smithsonian Expedition, and Mr. Perrine, in charge of the Crocker Expedition from the Lick Observatory, were prepared, with four cameras each, to secure duplicate photographs covering a large area extending east and west from the sun. Conditions were unfortunately against the success of Mr. Abbot's plans, but thin clouds at the time of the eclipse let 25 per cent. of the light come through to Mr. Perrine's photographic plates. The area covered in duplicate was 6° x 38°, extending along the direction of the sun's equator, with the sun in the center of the region. The plates recorded 170 well-known stars; and all apparent images not of ordinary stars were proved by the duplicate plates to be defects in the films. In two thirds of the area stars down to the eighth magnitude and many fainter ones were recorded; and in one third the area, covered with thicker clouds, stars were recorded down to the fifth and sixth magnitudes.

At the eclipse of 1905 Mr. Crocker made it possible for me to organize expeditions to Labrador, Spain and Egypt, each equipped with four intramercurial cameras, in addition to apparatus for other lines of research. The details of the twelve cameras were planned by Dr. Perrine, the instruments were constructed under his supervision, and any photographic plates obtained with them at the three stations were to be assigned to him to examine for possible intramercurial-planet images. The Labrador group of four cameras, mounted at the station by Dr. Curtis, made no contribution because of the severe storm conditions prevailing at the time of totality. The Egyptian cameras, mounted by Professor Hussey, recorded a considerable number of stars, but the sky, though clear in the usual sense, was full of dust, and the sun and the surrounding region covered by the search were at a low altitude. The Spanish cameras, photographing through clouds which permitted only 20 or 30 per cent. of the light to pass, recorded 55 stars down to about the seventh and eighth magnitudes. All suspected images not occupying the positions of known stars were proved to be defects in the films.

The eclipse of 1908 in the South Seas was utilized by the Crocker Expedition to cover a region extending east and west along the sun's equator with duplicate exposures. Notwithstanding interference from rain and clouds at the beginning of totality, clear sky prevailed during the last two thirds of the four critical minutes. Dr. Perrine finds more than 500 images of well-known stars on the plates, and no images of unknown bodies. Stars are recorded down to nearly the ninth visual magnitude.

It is not absolutely certain that intramercurial planets, revolving around the sun in elliptical orbits would be seen in projection entirely within the area 9° x 29° lying along the solar equator and equally east and west of the sun's center, yet there are exceedingly strong reasons to believe such would be the case. The eight large planets and the 650 ± minor planets in our system revolve around the sun in the same direction and, excepting a small proportion of the asteroids, so nearly in the sun's equatorial plane that the parts of their orbit planes lying within the limits for intramercurial planets would be projected upon the photographed area. The central plane of the zodiacal light differs little from the sun's equatorial plane. It is certain, also, that any intramercurial planets originally moving in planes inclined at large angles to Mercury's orbit plane would gradually be compelled by the attractions of Mercury and the other major planets to move in planes inclined at small angles to the ecliptic. The coincidence of the satellite planes in the systems of Jupiter and Saturn, and no doubt of Uranus and Neptune also, with the equatorial planes of these planets is another analogy of some weight. Admitting, for completeness, the hypothesis of an extensive system of small planets moving in planes making a variety of angles with the ecliptic and sun's equator, some would certainly have been caught in the region photographed. A single planet, or a half dozen planets, massive enough to meet the requirements, moving in *any* orbit planes would no doubt have been discovered a generation ago. In view of these facts, there is little reason to fear that any planets effective in disturbing Mercury's motions were north or south of the regions covered by photography.

Inasmuch as planets, shining by reflected light, do not act upon photographic plates so strongly as stars of the same visual magnitude, we may say that exposures which recorded stars down to the ninth magnitude should have recorded planets down to the eighth. From the known brightness, distance from the sun and approximate diameter of a few of the asteroids revolving in space between Mars's and Jupiter's orbits, Dr. Perrine has computed that an average eighth-magnitude intramercurial planet could scarcely be larger than thirty miles in diameter and that roughly a million such bodies, of great density, would be required to supply the disturbing effect observed in Mercury's orbit.

Taking all these points into consideration, I think we may say that the investigations by Perrine, forming a part of the work of the Crocker Eclipse Expeditions from Lick Observatory, have brought the observational side of the Intramercurial Problem, famous for a half century, definitely to a close. It is not contended that no such planets will be discovered in the future: in fact, it would not be surprising, nor in opposition to the opinions here expressed, if several such bodies should be found: but it is confidently believed that any such bodies would fail hopelessly to supply the great mass of material demanded by Le Verrier's theory, as Perrine pointed out in discussing the Sumatra observations of 1901.

On the occasion of a future eclipse of fairly long duration, occurring in the dry season, it might be well to repeat the observations, inasmuch as the instruments are in approximate readiness, and the observations at the three past eclipses were made through thin clouds twice, and with cloud-shortened exposures the third time. The cameras are capable of recording tenth-magnitude stars with three-minute exposures in clear sky. It will not be advisable to use these instruments at the eclipses of the next four years.

There are other chapters, on the theoretical side of the problem, to be entered here.

Professor Newcomb's researches on planetary motions extended much further than Le Verrier's. He found small terms in the motions of *all* the inner planets—Mercury, Venus, Earth, Mars—which are not due to the disturbing attractions of any known masses of matter. The chief discrepancies, aside from the large one found in Mercury's motion by Le Verrier and confirmed by Newcomb,[1] are in the perihelion of Mars, and in the nodes of Mercury and Venus. These outstanding residuals will be tabulated on a later page.

The attractions of any one planet or ring of small planets, sufficient to account for the excess motion of Mercury's perihelion, failed to account for the other discrepancies discovered by Newcomb for the

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[1] Le Verrier's discrepancy amounted to 38″, Newcomb's to 41″.

four planets. Satisfactory causes were looked for in a possible ellipsoidal form of the sun, in a hypothetical ring of small planets between Mercury and Venus, in an assumed minute variation in the law of gravitation from the Newtonian inverse square of distances, and in other assumptions, but in vain. One hypothesis, that the finely divided material which gives rise to the zodiacal light (by reflecting the sun's rays) is the responsible disturbing mass, has been discussed several times since the days of Le Verrier and as many times rejected, with one exception.

The exception is Professor Seeliger's recently published investigation. With great skill and with entirely reasonable assumptions as to the form of space occupied by the zodiacal material, and as to the density of the distribution of the material in this space, he establishes that there is sufficient mass to account for the discrepancies in the motions of all the four planets.

The following table exhibits the results of Seeliger's theory in the first column of figures, and the actual results of observation as determined by Newcomb in the second column. The quantities in the third column, which bear the sign ±, are the "probable errors" assigned by Newcomb to his results; and, for the benefit of non-mathematical readers, we may explain that these "probable errors," deduced from the observations themselves, are indications of the uncertainties existing in the quantities to which they are attached. In this table e and i are respectively the eccentricity of the orbit and the inclination of the orbit plane to the ecliptic; and $\Delta\Pi$, $\Delta\Omega$ and Δi are respectively the changes, per century, in the longitude of perihelion, in the longitude of node and in the inclination of the orbit plane, unaccounted for by the attractions of known masses, as in the second column, and produced by the attractions of the zodiacal matter as computed by Seeliger. In the last column are the differences between the Seeliger and Newcomb numbers: in other words, a comparison of theory with actuality. These differences are small. All are within the probable errors in the third column; with one exception, far within these probable errors.

We can not ascribe this remarkable agreement between Newcomb's

		SEELIGER	NEWCOMB		N-S.
		″	″	″	″
$e \cdot \Delta\Pi$	Mercury	+ 8.49	+ 8.48	± 0.43	— 0.01
	Venus	+ 0.05	— 0.05	± 0.25	— 0.10
	Earth	+ 0.07	+ 0.10	± 0.13	+ 0.03
	Mars	+ 0.59	+ 0.75	± 0.35	+ 0.16
$\sin i \cdot \Delta\Omega$	Mercury	+ 0.65	+ 0.61	± 0.52	— 0.04
	Venus	+ 0.58	+ 0.60	± 0.17	+ 0.02
	Mars	+ 0.23	+ 0.03	± 0.22	— 0.20
Δi	Mercury	+ 0.52	+ 0.38	± 0.80	— 0.14
	Venus	+ 0.17	+ 0.38	± 0.33	+ 0.21
	Mars	— 0.02	— 0.01	± 0.20	+ 0.01

and Seeliger's results to fortunate chance, and it is scarcely possible to doubt that in the zodiacal-light materials lie the causes of the discrepancies referred to. I have little hesitation in venturing the opinion that Seeliger's investigation marks an epoch in the application of Newton's law of gravitation to the motions within the solar system. At one stroke he appears to have removed a group of discrepancies which served as bases for many inquiries as to the preciseness and sufficiency of the Great Law. With all respect to Seeliger's genius and labor, however, scientific caution will value confirmation of his results by other investigators.

Seeliger's assumptions as to the distribution and mass of the zodiacal material are of interest, especially when we recall that the zodiacal light within some 20 degrees of the sun is unobservable, on account of the glare, and that the brightness of the light is a poor index to the mass: a given quantity of matter, finely divided, would reflect sunlight more strongly than the same quantity existing in larger particles. For the mathematical development of the subject he assumed that the material is distributed throughout a space represented by a much-flattened ellipsoid of revolution whose center is at the sun's center, whose axis of revolution coincides more or less closely with the sun's axis, whose polar surfaces extend 20 or 30 degrees north and south of the sun (as viewed from the earth), whose equatorial regions extend considerably beyond the earth's orbit, and in which the density-distribution of materials decreases as a function both of the linear distance out from the sun and of the angular distance out from the equatorial plane of symmetry. According to these assumptions, surfaces of equal densities are concentric ellipsoidal surfaces, and the number of such ellipsoids can be increased or decreased according as the computer may desire to represent more or less closely any assumed law of density-variation within the one great spheroid. Practically, Seeliger found that the disturbing effects on the planets are almost independent of the law of distribution of the material, as related to distance from the sun, as far out as two thirds of the distance to Mercury. He made use of only two ellipsoids: One with equatorial radius 0.24 unit[2] and polar radius 0.024, of uniform density; and the other with corresponding radii 1.20 and 0.24, of uniform but much smaller density. The total mean densities determined for his volumes, on the basis of unity as the mean density of the sun, are, respectively, 2.18×10^{-11} and 3.1×10^{-15}; and the resulting combined mass of the two ellipsoids is 3.1×10^{-7} of the sun's mass, which is roughly twice the mass of Mercury. The corresponding density of mass-distribution is surprisingly low. In the inner and denser ellipsoid, the matter, if as dense as water, would occupy 1 part in 30,000,000,000 of the space; if as dense as the earth, only 1 part in 160,000,000,000.

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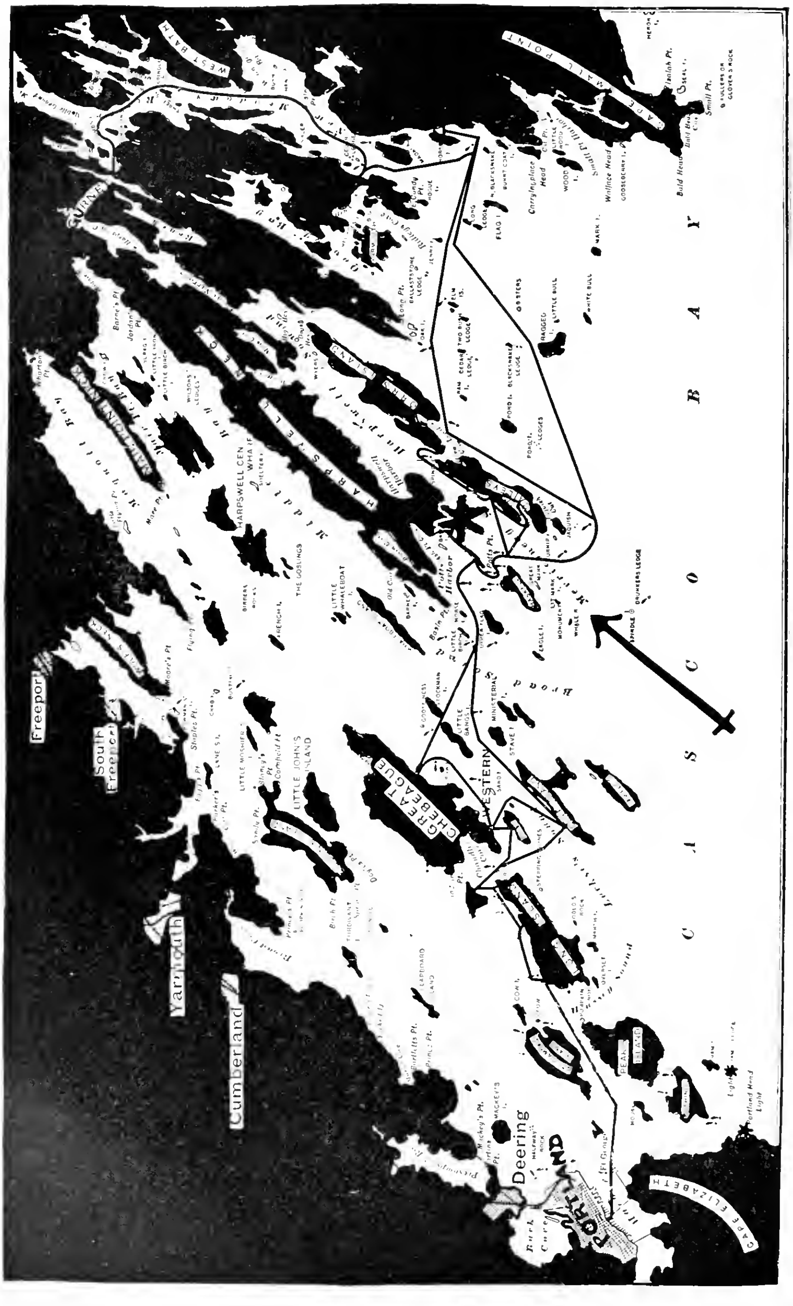
[2] The distance from the sun to the earth being 1.00.

The reader should be cautioned against obtaining the impression that Seeliger's two ellipsoids represent the truth as to the law of distribution of density, for such is not the case. A very large number of ellipsoids, doubtless decreasing rapidly in density as one proceeds from the sun outward, would be required to represent the actual law. Seeliger found that the attractive effect of the mass inside of the ellipsoid with maximum radius 0.24 was essentially independent of the law of distribution; and for convenience in the computations he therefore assumed the density in the said ellipsoid to be uniform. A solution based upon a greater number of constituent ellipsoids would perhaps be a slight improvement.

The logic of Seeliger's work rests finally upon the reasonableness of his assumptions and deductions concerning the distribution and density of the zodiacal-light materials; and these are not out of harmony with the meager knowledge of the zodiacal light which we have obtained by direct observation.

In consequence of Seeliger's results further direct observations of the zodiacal light take on renewed interest.



CASCO BAY AND THE SITE OF THE HARPSWELL LABORATORY.

THE HARPSWELL LABORATORY

By MAX MORSE

THE COLLEGE OF THE CITY OF NEW YORK

> Whether one is sailing about upon the sunny sea, fishing with muslin nets for the surface fauna, or steaming away far from shore to dredge for other material, or, again, carrying on observations in the cool sea water tanks and bell-jars of a neat little wooden workshop thrown open to the sea-breezes, it alike requires some effort to persuade one's self that the occupation is really something more than that of finding amusement.—Romanes, "Jellyfishes, Starfishes and Seaurchins."

ROMANES was thinking of Cromarty Firth when he drew this beautiful *vignette*. One may equally well think of the "little wooden workshop" founded by John Sterling Kingsley on Casco Bay.

As it stands at present, the laboratory is a one-story, wooden building, 24 by 42 feet on the ground, with sixteen windows looking out directly on a rugged shore, where the long ground swells from open water break incessantly. The building, within, is divided up into nine small rooms for investigators, and one large room, which is fitted up with five tables, for other workers, as occasion demands. A portion of this space is given over to shelving for the nucleus of a library made up mainly of books from the private library of Dr. Kingsley and reprints given to the laboratory by various students. Arrangement is made whereby the current journals are placed on file, during the season, and back numbers may be obtained for the asking, either from Tufts College or from the Boston Society of Natural History. At either end of the laboratory are double doors and when these are "thrown open to the sea breezes" an ideal temperature is assured, even on the warmest days. There have been but few days for many years when the thermometer in the laboratory registered above 78° F.

The equipment of the laboratory, modest as it is, has been found adequate for the purposes. Whenever special apparatus has been called for it has been supplied without delay, either from Portland, which is within an hour and one-half by the line of steamers running down the bay, or from Boston, which may be reached within three hours. Microtomes, glassware and the commoner laboratory materials are brought at the beginning of the season from the zoological laboratory of Tufts College. Investigators, even in our larger laboratories, prefer to take with them their more special apparatus, and such workers have been requested to do so when applying for space at the Harpswell station.

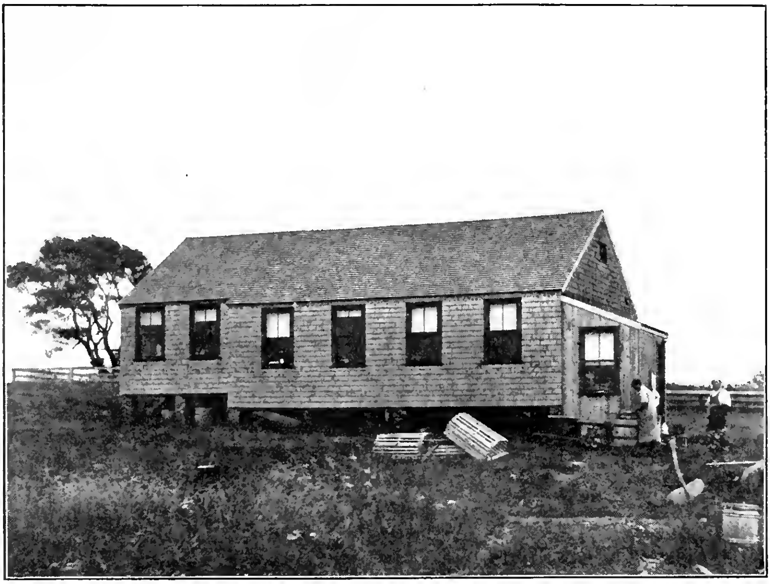


FIG. 1. THE LABORATORY, LOOKING SOUTHEAST. The sea reaches the bluff immediately beyond the fence. The writer is indebted to Professor H. V. Neal for the use of the photographs reproduced in this article.

One feature may appear, to some investigators, a serious drawback, and that is the lack of running water. The experience, however, of those who have carried on protracted series of experiments involving the keeping of living material throughout the season has been that no inconvenience has been felt by the absence of running water. The main reason for this is that the temperature is so low that one may keep material standing in dishes in the laboratory for many days without even changing the water. Thus one may keep hydroids, echinoderms, and even the "candles" of dog-fish without difficulty.

The laboratory is supplied with several small boats and with a motor boat, similar to the one which is used by the fishermen of Casco Bay. It is wonderfully seaworthy and safe, and for the collector it is ideal. If occasion demands, additional motors may be rented at low fees by the day or week from the fishermen. An ample supply of seines, dredges and trawls is maintained at the laboratory. The stock of chemicals and reagents is large, and whenever additional supplies of this character are required they are readily obtained from the larger dealers of Portland, who keep constantly on hand all but the more exceptional reagents. In fact, this city may be drawn upon for supplies rarely found in other cities of its size.

Accessibility to the laboratory is assured. The city of Portland is the terminus of the Grand Trunk System, and of the Boston and Maine and Maine Central railways and of several coastwise lines. The Maine

Steamship Company maintains throughout the year a line of steamers between this port and that of New York. A day line and a night line of steamers ply between Portland and Boston, while the down-east ports, St. Johns and the St. Lawrence country are made accessible by other steamship lines. In general, the rates of passage on these lines is low and there is afforded a most comfortable and convenient mode of travel.

The laboratory is situated in the little fishing village of South Harpswell. A line of steamers sending a boat from Portland every two hours, on the average, throughout the day, is utilized in the main for reaching the laboratory. One may, if he desire, go overland to Brunswick, the seat of Bowdoin College, fourteen miles up Harpswell Neck. From Brunswick, Portland may be reached by trolley or by rail, or by a line of steamers running from the New Meadows River to Portland.

The Portland Public Library and the Library of the Portland Society of Natural History may be called upon for literature not supplied at the laboratory. The latter institution has, too, collections of the animals and plants from the surrounding region, identified by some of our well-known systematists, such as Emerton and others.

It is not, however, the buildings and accessories that attract the worker, but rather the living material. Harpswell has nothing to fear in rivalry with sister laboratories, wherever they may be, in wealth of material. In order to set this feature of the case clearly before the

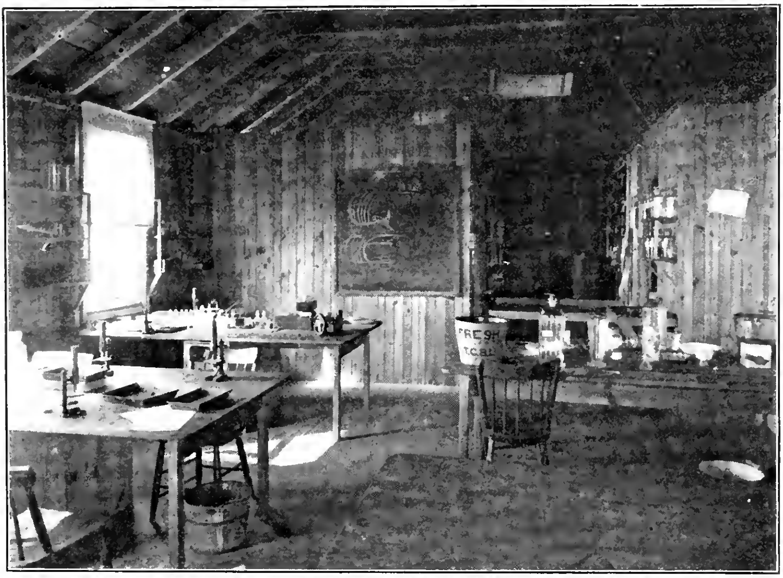


Fig. 2. Interior of the Laboratory, looking northward.

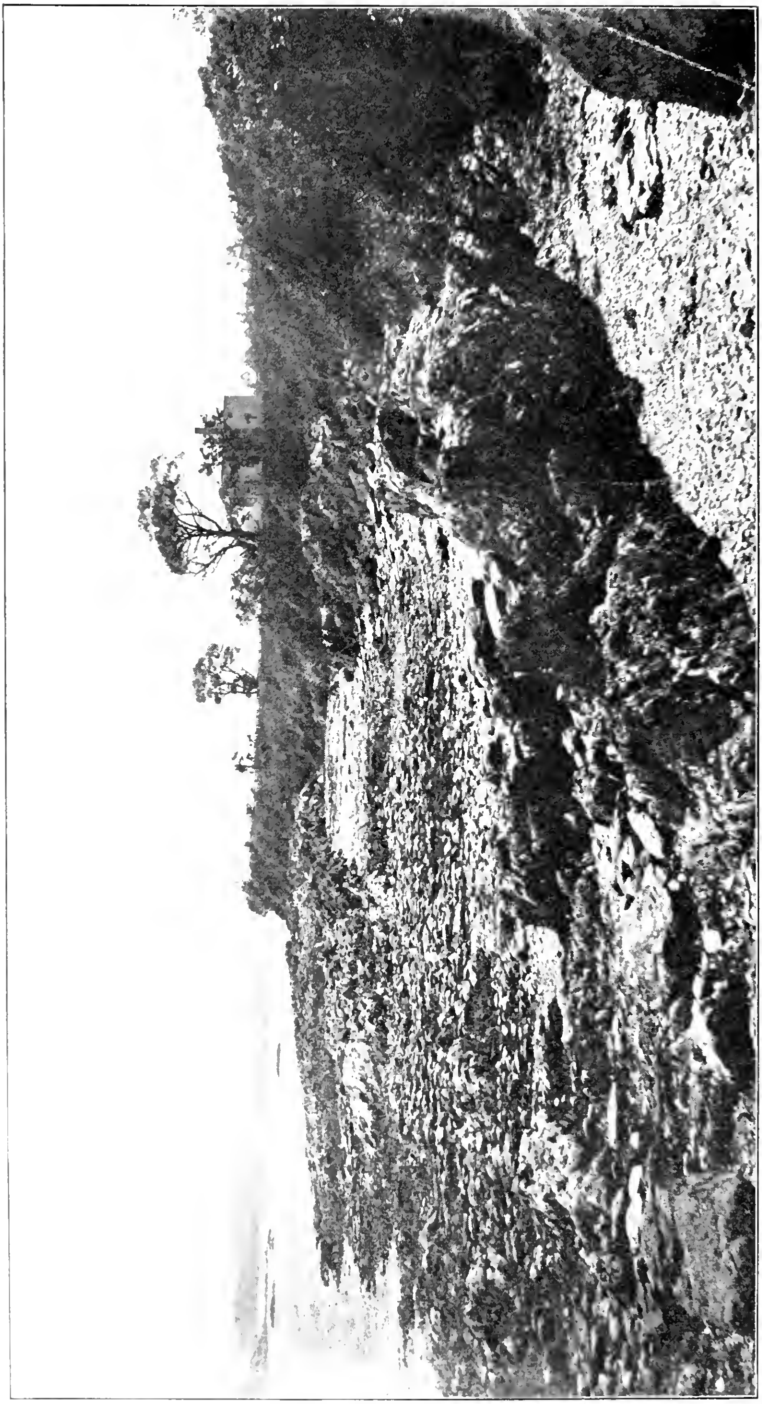


FIG. 3. THE LABORATORY BEACH AT LOW TIDE, looking towards Professor Kingsley's house, immediately beyond which is the laboratory.

reader, it will be necessary to describe briefly the geography of the region.

No geologist has described the rock formation of Casco Bay, although many of the more salient points in its history are evident. A glance at the accompanying map will show that the bay is dotted here and there with islands, none of which are more than three miles in length. It is popularly said by the denizens of the region that there are as many islands in the bay as there are days in the year. However that may be, it seems to the traveler who is making his first visit by the little steamer threading through the devious passages between the islands, that the estimate has been too meager. Extending down from the mainland are several long ragged points of land. Harpswell is one, Cape Small Point is another. The axes of these peninsulas lie parallel with those of the islands and between the islands and the peninsulas are deep lagoons bordered by the steep high sides of the islands. The average depth of these lagoons is fourteen fathoms, although a greater depth is reached in some places. At the westward, Cape Elizabeth forms the boundary for the bay.

A portion of the Arctic current flowing down the Gulf of Maine from the Greenland and Labrador shores is deflected into the immediate vicinity of Casco Bay, giving the cool water and the cool air characteristic of the locality. The Gulf Stream lies beyond this cold current and, while rarely a bit of the fauna of this stream comes into the bay, its effect is practically nothing on the plant and animal life. The dense fogs so characteristic of some of our other laboratories, nearer the Gulf Stream, are nearly absent here. It is mainly for this reason that one may safely use apparatus at the laboratory without injury from rust and hydroxide and oxide depositions. The writer, during the past season, used apparatus of great delicacy, such as is seldom brought out of the city workrooms, in investigating the contractions of muscle in various invertebrates, without any deleterious effect being produced by its sojourn at the coast.

The geological structure of the region is such that the retreating tides leave tide-pools filled with a wealth of animals and plants. The range of the tides is great, averaging fourteen feet. The cleavage planes of the mica schist and slate are normal to each other so that square or rectagonal holes are left for the formation of the tide-pools. Here may be found *Asterias*, *Strongylocentrotus*, *Metridium*, *Tetrastemma*, *Carcinus*, *Cancer* and dozens of other species. The algalogist is well rewarded for any labor he may expend in working these pools. The lagoons were gouged out in preglacial times and therefore the rocks are bare and free from till and boulders to a great extent. The subsidence of the whole region in later times has deepened the water throughout the bay, and these deep lagoons are carpeted with immense

Laminaria and the perforated *Agarum,* belonging to the same group. The surfaces of the islands bordering the water stretches and of the peninsulas pushing seaward from the mainland are covered with evergreens, while as one passes up the sounds towards the mainland proper this evergreen growth gives place to deciduous trees. Hence, within a comparatively short distance, the botanist may have a wide range of vegetation.

Out "upon the sunny seas" float *Aurelia flavidula* and *Cyanea arctica* in countless numbers. *Melicerta* and Pteropods occur during the greater part of the season, and these may be collected in a rowboat within the sounds themselves. On shallow banks of sand exposed entirely at low tide *Echinarachnius parma* may be collected in quantities, and with great ease. *Strongylocentrotus dröbachiensis* is dredged by the bushel within a mile of the laboratory, while the same dredgings bring up *Dentalium, Corymorpha, Chalina, Edwardsia, Pentacta, Terebratulina, Pecten tenuicostata, Boltenia* and other classics.

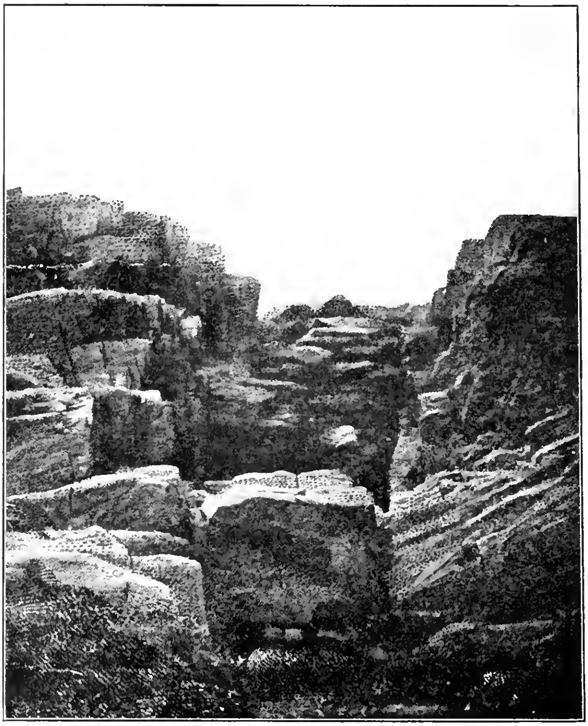


Fig. 4. Typical Rock Structure forming the Tide-pools.

The one-day trips from the laboratory may be undertaken in one of many directions. Twenty miles is generally a recognized limit. The map reveals the possibilities of a day's collecting. All the trips are in sheltered water or within safe distance of harbors, and the strong tide sweeps which are familiar to the collector at many of our other laboratories are not present here, except in one or two points, hence the fear of being carried away from the collecting ground never disturbs one.

A mile from the laboratory is the site of the Old Tide Mill, now no more, but represented by the rapids which served in former years to turn the wheels of the mill. The open sea is led in communication with a large tidal pond by a long, narrow cove, at the narrowest portion of which the old mill once rested. Through these narrows and over the rocks the tide rushes at twelve knots an hour into the pool at rising tide and out again at falling tide. Beneath these rocks is a veritable curiosity shop for the novice and an Eldorado for the biologist. An invoice from the overturning of a single stone, in genera, is given as follows: *Tethya, Cliona, Tubularia, Clava, Metridium, Asterias, Cribrella, Ophiopholis, Ophioglypha, Strongylocentrotus, Pentacta, Tetrastemma, Lepidonotus, Spirorbis, Membranipora, Balanus, Pagurus, Cancer, Carcinus, Idothea, Purpura, Æolis, Molgula, Leptoclinum* and *Amaroucium*. The most fastidious could scarcely ask for a greater galaxy.

Across the cove and opposite the mill-site is a fishermen's village. Here are brought in, from the open water and the sounds, fish of all descriptions. Aside from the food fishes, such as rock cod, hake, pollock and the like, these men may, at the request of the laboratory, bring back numbers of sand-sharks, rays and dog-fish, the "candles" or egg-cases of which afford possibilities for embryological studies, both descriptive and experimental, hitherto scarcely recognized. The abundance of the material supplied by these fishermen is taken advantage of by Professor F. D. Lambert, who maintains a supply station for zoological material in connection with the laboratory on Harpswell. Nowhere, to the writer's knowledge, is such an abundant supply of choice material made available to the zoologist.

Nearer the laboratory, on the sandy shores of a neighboring island, *Nereis* and *Sipunculus* may be dug in large numbers. *Cerebratulus*, represented by two species, one being the giant form, occurs near the "bridge," while *Balanoglossus, Pholas, Zirphœa* and other interesting and important forms, from the point of view of the experimentalist, are to be found in the same vicinity. But it is impossible to go on. One would of necessity give a catalogue of the fauna of Casco Bay if he desired to do the matter justice.

The history of the laboratory is brief. The late Professor Lee, of Bowdoin College, insisted upon the desirability of establishing a station for the study of marine forms in the Gulf of Maine, and specifically in Casco Bay. In 1898, Professor Kingsley, together with a band of students from Tufts College, leased a cottage near the present site and

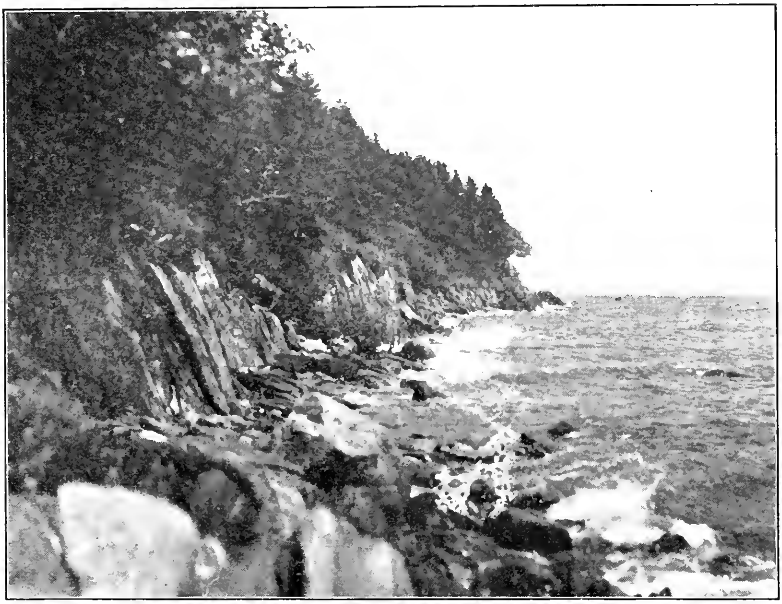


FIG. 5. THE COAST AT HIGH TIDE. Compare with Fig. 3.

converted it into a laboratory on the lower floor, while the upper chambers were made living rooms. Then, in 1901, Tufts College bought a tract of land and erected the present building, opening it for the use of students for the first time in the summer of the same year. Later on, an addition was made to the rear of the building. For the first years, undergraduate instruction was maintained in the laboratory, but in 1906, this was abandoned. Now, all the expenses of the laboratory are met from the small fee paid by each investigator, which is made for the use of room and material. For the coming season, a new arrangement has been made whereby funds other than those supplied by the workers will be available and a collector will be ready to bring to the investigator whatever material he may desire. Additions, too, to the library and to the supplies and possibly to the building itself are planned and if not completed during the coming season, they will be made in the near future.

Living facilities, a matter of concern to the average investigator at the summer laboratory, are at their best. One may find almost any mode of living he may desire on Harpswell. If he desires a first-class hotel, he has the choice of three. If he prefer to live in a private house and obtain his meals either in the same house or one within easy access, he may do so. If he desire a cottage, he may obtain one at low rental for the season. The average rental for a five-room house is seventy-five dollars, for the season, beginning as early and ending as late as one desires. Country produce may be engaged and delivered at your door,

FIG. 6. A VIEW IN THE EVERGREENS, one half mile from the laboratory.

at very reasonable rates, while grocers supply the best provisions, being in the main those brought fresh from Portland, a city well known for its splendid markets. Finally, camping is possible, either near the laboratory, or farther away amongst the evergreens.

With a delightful climate, plenty of sunshine and clear sky, a rich fauna and flora, good facilities for carrying on investigation, a comfortable summer home, freedom from the conventionalities of our more formal stations, ease of access—certainly Harpswell has few rivals.

The biologist is notorious for being ever busy. "I have no vacations," complained an entomologist; "there are ants wherever I go." The ability of the biologist to work incessantly is easily explained; his work is his play. Emphatically is this so of the investigator at Harpswell.

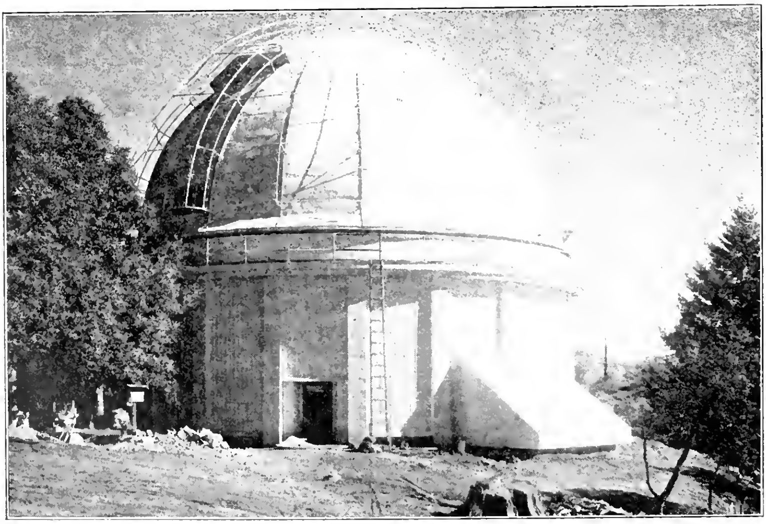
THE PROGRESS OF SCIENCE

THE RESEARCH WORK OF THE CARNEGIE INSTITUTION

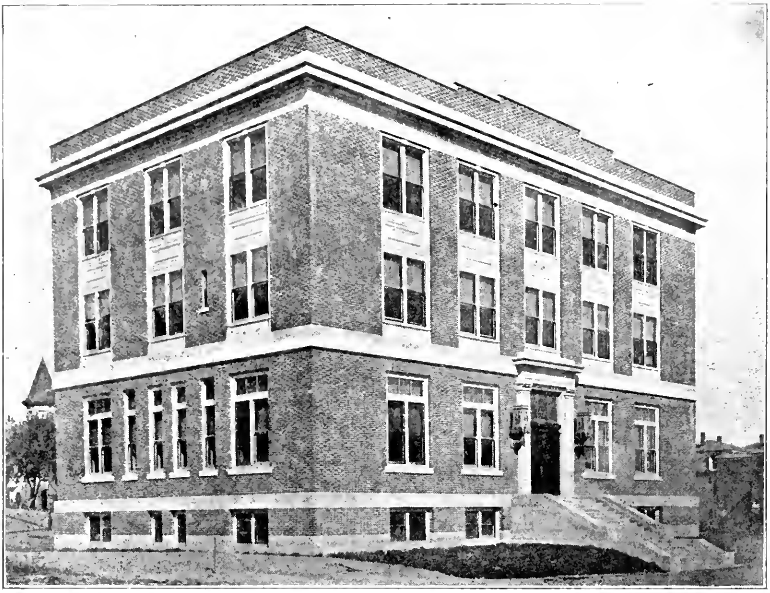
THE seventh year book of the Carnegie Institution of Washington, like its predecessors, gives an interesting account of the investigations carried on last year. The work is now in the main conducted by its departments; only a few minor grants are made to scientific men in other institutions, and these are nearly all in continuation of work begun when it was the policy to distribute the larger part of the income in special grants.

The institution has now ten departments, or twelve, if the *Index Medicus* and the horticultural work of Mr. Luther Burbank are included. Two of the principal departments are in astronomy, two in geophysics, three in biology, one in physiology and two in economics and history. The amount of the grants for these departments last year was: astronomy, $105,000; geophysics, $139,000; biology, $70,000; physiology, $35,000; economics and history, $50,000. There was a special grant of $50,000 for publications.

In astronomy the institution conducts the solar observatory on Mount Wilson in California, under the directorship of Dr. George E. Hale, and last year established an observatory in Argentina for meridian astrometry, under Dr. Lewis Boss. The solar observatory has made notable progress in its elaborate installations and has carried forward research work in several directions. The 60-inch reflecting equatorial telescope has been mounted in a new steel dome, and the tower telescope and the horizontal telescope, together with the spectroscopic laboratory in Pasadena, have been in use. The most important work relates to sun-spots and flocculi, giving new results in regard to the constitution and rotation of the sun. The study of the motion and structure of the stellar system has been continued in the Dudley



STEEL BUILDING AND DOME FOR THE 60-INCH REFLECTOR.



THE NUTRITION LABORATORY AT BOSTON.

Observatory at Albany and is now being extended to the southern hemisphere in the observatory erected at San Luis in the Argentine Republic, where the work is under the immediate charge of Professor R. H. Tucker, who has been given leave of absence from the Lick Observatory for this purpose.

The work in terrestrial magnetism under Dr. L. A. Bauer includes the completion of the third cruise of the *Galilee* on the Pacific, where altogether over 60,000 nautical miles have been covered in regions where magnetic data were especially needed. With the extensive work done on land in different countries by the institution and by other agencies a new set of magnetic charts covering nearly one third of the globe can now be constructed. A new magnetic survey yacht is being built, which, on its completion this summer, will be sent to the north Atlantic. The geophysical laboratory at Washington, of which Dr. A. L. Day is director, is now in efficient working order and has entered on a systematic study of rock formation, with excellent equipment for producing such effects of temperature, pressure, etc., as may have occurred in the history of the earth's development.

In biology, the institution supports a desert botanical laboratory in Arizona; a station for experimental evolution on Long Island and a marine biological laboratory in one of the Tortugas Islands. With the desert laboratory at Tucson as headquarters, very interesting experiments are being made on the effects of moisture, altitude, etc., in plants, including a study of the vegetation following the receding area of the Salton Sea. Especially noteworthy have been the experiments of Dr. D. T. MacDougall on the production of new kinds of plants by subjecting the reproductive organs to chemical action. Elaborate experiments in breeding have been carried forward under the direction of Dr. C. B. Davenport at Cold Spring Harbor, Long Island, including the crossing of poultry, canaries, cats, sheep, goats, insects and plants, and observations on human traits, which give quantitative data of importance for determining the laws of heredity. The station at Dry

Tortugas, under Dr. A. G. Mayer, offers admirable facilities for marine biological work of certain kinds of which some ten investigators took advantage.

The nutrition laboratory, under Dr. F. G. Benedict, was last year in the stage of construction and equipment. It is adjacent to the Harvard Medical School and several hospitals, which will give opportunity to work with pathological cases. In the new building, shown in the accompanying illustration, work is now beginning with the calorimeter and in other directions.

The work of the institution in economics. sociology and history has consisted in the collection of data and the classification of records. The department of economics and sociology has suffered through the recent death ot the director, Dr. Carroll D. Wright. No work, or hardly any, has been done in anthropology, psychology, philology, literature or art.

Some twenty-four publications were issued by the institution during the year at a cost of about $64.000. The administration building at Washington, erected at a cost of about $220,000, at the southeast corner of Sixteenth and P streets, is now nearly ready.

LIEUTENANT SHACKLETON'S ANTARCTIC EXPEDITION

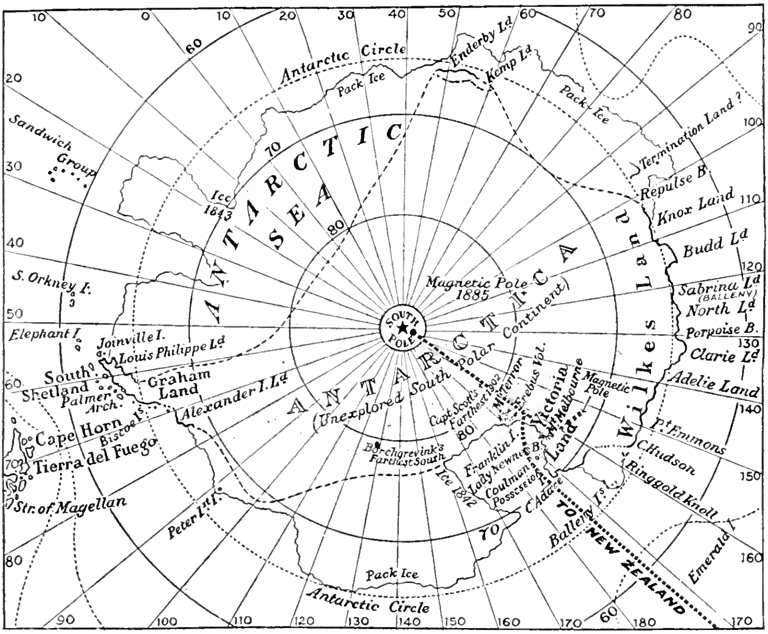
Lieutenant Shackleton's expedition has been remarkably successful, whether viewed as adventure or as scientific exploration. The results are the more noteworthy in view of the unofficial character of the expedition and its somewhat modest outfit. The expedition seems throughout to have been accompanied by that kind of good fortune which may properly be attributed to expert knowledge and skilful foresight.

The *Nimrod*, it may be remembered, left New Zealand on January 1, 1908, and included in its scientific staff Professor Edworth David, F.R.S., of Sidney University, and Lieutenant Adams, R.N.A., geologists; Sir Philip Brocklehurst, surveyor and map-maker, and other scientific men. It had been Lieutenant Shackleton's intention to find a convenient place on King Edward's Land at the eastern end of the ice barrier, but the conditions were unfavorable, and it was necessary to take up quarters in McMurdo Sound, close to the place occupied by the *Discovery* in 1902.

The first expedition started on March 5 and ascended Mt. Erebus, the great Antarctic volcano, the summit of which, at an altitude of 11,000 feet, was reached on March 10. It was ejecting vast amounts of steam and sulphurous gas to a height of 2,000 feet.

The Antarctic winter was made use of for collections, observations and photographs. In the early spring, three exploring parties set out, one under Mr. Armitage going westward, gathering geological and topographical data; the second under Professor David going southward and reaching the magnetic pole on January 16 in latitude 72° 25″ and longitude 154° east. The party journeyed 1.260 statute miles in a hundred and twenty-two days, suffering many hardships and making important discoveries.

The most dramatic expedition, in which Lieutenant Shackleton was accompanied by Messrs. Adams, Marshall and Wild, left Cape Royd on November 29, taking with them four ponies. On December 26 they reached the *Discovery* expedition's southernmost latitude. Proceeding south and southeast they reached a high range of mountains and discovered a glacier 120 miles long and forty miles wide, which they ascended, contending with deep crevasses. On December 8 they discovered another great mountain range. On December 26 they reached a plateau at an altitude of 9,000 feet. During this time there was a constant southerly blizzard of wind and drifting snow, with temperature ranging from 37 to 70 degrees of frost. On January 9 they reached latitude 88° 23″ and longitude 162° east, the most southerly point ever attained and 1° 17′ nearer the pole than



Map of the Antarctic Region,
Showing the expeditions of the Shackleton parties toward the south geographical pole and to the south magnetic pole.—From the *Independent*.

Peary's farthest north. They were then 111 miles from the south pole, and saw a great plain without mountains stretching towards the south at an altitude of 10,000 or 11,000 feet above sea level. One pony after another had been killed and eaten, and during the latter part of the trip the supply of food had been reduced to a minimum. The return was accomplished with great hardships, the headquarters being reached on March 4, after an absence of 126 days, during which the distance of 1,708 statute miles was covered. Coal measures were found in the limestone, and eight distinct mountain ranges with over 100 peaks were discovered.

TWO GREAT FRENCH NATURALISTS

In the deaths of Jean Albert Gaudry and Alfred Giard, France has lost two naturalists of distinction, whose contributions to our knowledge of organic evolution were important factors in the most notable scientific advance of the second half of the nineteenth century. They both had in common with their great leader, Charles Darwin, an accurate knowledge of facts in broad fields of the natural sciences and a deep interest in theories and philosophical generalization. They shared fully the quick perception, wide insight and clear expression which are characteristic of French genius.

Gaudry was born near Paris in 1827; as a boy he was interested in natural science and the collecting of fossils. At the age of twenty-six he was appointed assistant professor of paleontology in the Paris Museum of Natural History. Before and after the publication of "The Origin of Species" he was engaged in his researches on the late Tertiary vertebrate fauna at Pikermi, near Athens, and on Mont Léberon. His work on the evolution of horses, rhinoceroses and other animals of these regions is of fundamental and classic importance. Other re-

Jean Albert Gaudry.

searches followed, including work on the Patagonian vertebrates, and much attention was given to the collections of the museum. Wide influence was exerted by his less technical writings in paleozoology and organic evolution.

Giard was born in 1846 in Valenciennes; like Gaudry and so many other naturalists, he was eagerly interested in nature and in collecting as a child. He became professor of natural history at Lille in 1873, and in 1888 there was established for him at the Paris Sorbonne a chair of "evolution of organic beings," a valuable step that should be followed by other universities. In the meanwhile, Giard had in 1874 founded at Wimereux, near Bologne, a marine biological station from which there have been issued not fewer than fifty volumes containing a vast amount of important research. His own work covered nearly the whole range of the biological sciences and extended to botany. Perhaps his work on parasitology is best known, but his researches are encyclopedic in their extent, equally at home in minute details and in broad theories.

Alfred Giard.

SCIENTIFIC ITEMS

We regret to record the deaths of Dr. H. M. Boyè, the chemist, who at the age of ninety-seven years was the only surviving founder of the American Association; of Dr. Persifor Frazer, the chemist and geologist of Philadelphia; of Mark Vernon Slingerland, who held the chair of economic entomology at Cornell University, and of Dr. William Jones, who was killed while engaged in anthropological explorations in the Philippines. Among foreign men of science, we note with regret announcements of the deaths of Dr. Hermann Ebbinghaus, professor of philosophy at Halle, and of Professor Arthur Gamgee, F.R.S., the physiologist.

The centenary of the birth of Oliver Wendell Holmes has been celebrated at Harvard University, where he was professor of anatomy and physiology from 1847 to 1882.—Congress has appropriated $5,000 for the erection of a memorial to Major J. W. Powell, on the brink of the Grand Canyon of the Colorado, which he explored.—The committee in charge of a fund for a memorial to the late Dr. Andrew J. McCosh announces that more than $100,000 has been subscribed. The fund will be devoted to some portion of the new buildings of the Presbyterian Hospital, with the surgical service of which Dr. McCosh was identified.—It is proposed to endow as a memorial to the late Dr. William T. Bull an institution for surgical research to be connected with the College of Physicians and Surgeons, Columbia University.

The Royal Academy of Stockholm has presented Mr. Thomas A. Edison with its Adelskiold gold medal for his inventions in connection with the phonograph and the incandescent light. This medal is conferred once in ten years.—The ambassadorship to Great Britain has been offered to President Eliot after his retirement from the presidency of Harvard University, but it is said that he is not likely to accept.

It is announced that President Taft has requested Surgeon General Wyman to draw up a tentative plan for the consolidation under one bureau of the agencies exercised by the federal government for the preservation of the public health.

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THE TIDES: THEIR CAUSES AND REPRESENTATION

BY ROLLIN ARTHUR HARRIS
THE UNITED STATES COAST AND GEODETIC SURVEY, WASHINGTON, D. C.

HISTORICAL NOTE ON THE TIDAL PROBLEM

THE so-called problem of the tides has for ages engaged the attention of observing and thinking men. Before Newton established the law of universal gravitation, the whole subject was surrounded with an air of mystery, although the fact had long been recognized by many that in some manner the tides are governed by the moon or the moon and sun. Such views were held by Pytheas of Massilia, Seleucus of Babylonia, Posidonius the Stoic philosopher, Cæsar, Cicero, Strabo, Seneca, Pliny the elder, Lucan, Claudianus and Macrobius.

The ancients say little as to the agency whereby the moon is enabled to exert an influence upon the waters of the globe; but winds produced by the moon, vapors surrounding the moon and the special power of the moon to replenish moist bodies, are severally mentioned as being the probable means.

However, before Newton's great discovery, several philosophers had gone so far as to suggest or assert that the tides are due to an attractive force of the moon analogous to magnetic attraction. Among these were Scaliger, Gilbert, the College of Jesuits at Coimbra, Antonio de Dominis, Stevin and especially Kepler.

Of course, not all ancient or medieval theorists admitted the moon to be the cause of the tides. Some of the many other causes brought forward were: The discharging of rivers into the sea; variations in depths and densities of the sea; the surface of the sea not being everywhere upon the same level; the respiration of the earth; submarine caverns; submarine heat; submarine vapors, exhalations, or fermentations; power exerted by a supernatural being; whirlpools and eddies; and the non-uniform motion of the earth or of its various parts.

When Newton had made public his capital discovery, and had shown that the magnitudes or ranges of the tides increase and decrease in accordance with the varying attractions of the moon and sun, the tidal problem was supposed to be nearing a solution. Indeed, Newton thought that he could see in the observed times of tides upon certain shores a justification of his theoretical considerations. His work, however, was only a beginning. Since his time, eminent mathematicians, astronomers and physicists—including Bernoulli, Maclaurin, Euler, Lalande, Laplace, Young, Lubbock, Whewell, Airy, Ferrel, Kelvin, Darwin, Lévy and Hough—have addressed themselves to this subject; while others, like Lagrange, Stokes, Rayleigh, Lamb and Poincaré, have dealt rather with the underlying mathematical and physical problems.

Since it has been universally recognized that the tides result from the attraction of the moon and sun, the popular mind has taken little interest in the manner in which these forces operate in order to produce the tides. The apparent hopelessness of the task has doubtless deterred many investigators from devoting to it a full measure of their attention. In fact, as will be shown below, there is no such thing as "the tidal problem" analogous to the astronomers' "problem of three bodies." The tide involves a number of problems, and to even discover what these problems are requires a good knowledge of the forms, sizes and depths of the oceans, together with a knowledge of the tide-producing forces. The observed tides themselves render great assistance in this matter; for their times and ranges indicate the ways in which the various oceans probably oscillate, and so, in a measure, the underlying tidal problems requiring solution.

General Belief in a Westwardly-progressing Tide Wave

Various theories were instrumental in leading to the belief of a general westward progression of the tide. As before the Copernican system of astronomy became known or generally accepted, the tides were made to accord with the Ptolemaic system then prevailing, so for some time before and after the publication of Newton's "Principia," the tides were made dependent upon the vortices of Descartes's theory.

The Ptolemaic system of astronomy assumed the center of the earth to be the fixed center of the universe around which revolved a series of concentric spheres. The outermost of these was styled the *primum mobile;* this by its westward motion imparted westward motion to the stars and other heavenly bodies, to the atmosphere, and even to the waters of the oceans. And so before the law of gravitation was established, the notion became prevalent that water had a westward motion (*ab oriente in occidentem* or *ab ortu in occasum*) around the globe; and because the flood stream, rather than the ebb, was the one chiefly considered, the flood stream (and so the progression of the tidal wave) was commonly supposed to partake of this westward motion. The theory of a westerly motion of the waters thus had its origin in the assumed motion of the *primum mobile.* The flood tide was associated with this westward motion by Scaliger and Bacon. Kepler also asserts that the flood has a westerly direction, although, as already stated, he attributes the tides to the attraction of the moon.

Descartes's vortex theory also gave a westward progression to the tidal wave because he assumed that low water would always occur when the moon crossed the local meridian.

Newton, Bernoulli and Laplace evidently contemplated tide waves progressing westward around the earth, completing the circuit in 24 lunar hours, or 24 hours and 50 minutes solar time, although they were aware that the land masses must produce many irregularities in this hypothetical motion.

In order to see how any tide wave progresses, it is necessary to reduce to a common time. This is generally taken as Greenwich lunar time. Consequently, if tides in a given locality are found to follow the meridian passage of the moon by a certain interval (expressed in lunar hours), this interval must be increased by the longitude, expressed in hours, if the place be in west longitude and decreased if in east longitude. Places having high water at the same tidal hour are said to lie upon the same cotidal line.

The first extensive charts of cotidal lines were constructed by Whewell about 75 years ago; and these charts, or these charts slightly modified, have been in common use in atlases and astronomies ever since.

THE IMPORTANCE OF STATIONARY WAVES SUGGESTED

The analogy between the tides and the oscillatory motion of water in a vase, or other vessel, had been noted by many even before the moon's attraction had been universally recognized as the principal and primary cause of the phenomenon. But in order that the water should oscillate, it must first be disturbed from its position of equilibrium. Galileo imagined that he had found this necessary disturbance in the non-uniform motion of different parts of the earth as it rotates upon its axis and revolves about the sun.

César d'Arcons (1667) supposes the solid earth to move a short distance back and forth along its axis, thus causing the flood in the northern hemisphere to appear to move from south to north and the ebb in the reverse direction. According to his views the entire Atlantic Ocean is a huge vessel of water, the surface rising and falling considerably at the two ends (*i. e.,* in high latitudes), but having little vertical motion near the middle (*i. e.,* in equatorial regions), where he logically infers the horizontal motion to be great.

John Bryanston (1683) supposes the moon to produce in the earth a small east-and-west libration, not detected by astronomers, and this motion of the earth to cause the waters of the oceans to oscillate like water contained in vessels of various shapes and sizes.

While not questioning the fact established by Newton that the tides are primarily due to the attraction of the moon and sun, Admiral Fitz Roy attempts to explain the tides upon the assumption of stationary waves extending in an east-and-west direction across various portions of the several oceans. His wide experience as a navigator had familiarized him with the fact that throughout some extended regions of the ocean, the tides occur at nearly one and the same time; also that even for islands remote from the land, the amount of rise and fall is quite various.

Sir George B. Airy was the first person to make an extensive mathematical study of wave motion implied in tidal phenomena. While he does not point out how the ocean tides are produced, he shows that certain dependent bodies of water, and in particular the Irish Sea, must contain stationary waves. He establishes the theoretical result that the tides in a north-and-south canal extending from the equator to either pole must consist of a stationary wave.

William Ferrel suggests that, because of their unusual size, the tides of the North Atlantic may depend upon stationary waves extending in an east-and-west direction across the ocean; and, in particular, upon one extending between the coasts of Ireland and those of Newfoundland.

These, and other writers who have expressed similar views, failed to consider that an imperfectly bounded strip of the sea must have considerable width (as well as a suitable length) in order to make a stationary wave possible. They also failed to make any connection between the known tidal forces and the times of the tide.

This brings us to the subject proper, which involves an approximate explanation of the dominant ocean tides, it being manifestly unreasonable to expect accurate mathematical solutions of the problems involved.

It should be noted in passing that although Dr. Berghaus propounded no theories concerning the tides, his cotidal chart constructed in 1889 marks a radical departure from those previously constructed, and is in itself highly suggestive.

THE TIDE-PRODUCING FORCES

The tide-producing forces of moon and sun can be computed from well-established astronomical data, and there are no uncertainties connected with their determination, at least to a moderate degree of refinement. In this place it is necessary to say only a few words descriptive of these forces. The tide-producing force of the moon upon a particle of unit mass is the difference between the moon's attraction upon this mass and upon a unit mass situated at the earth's center; or

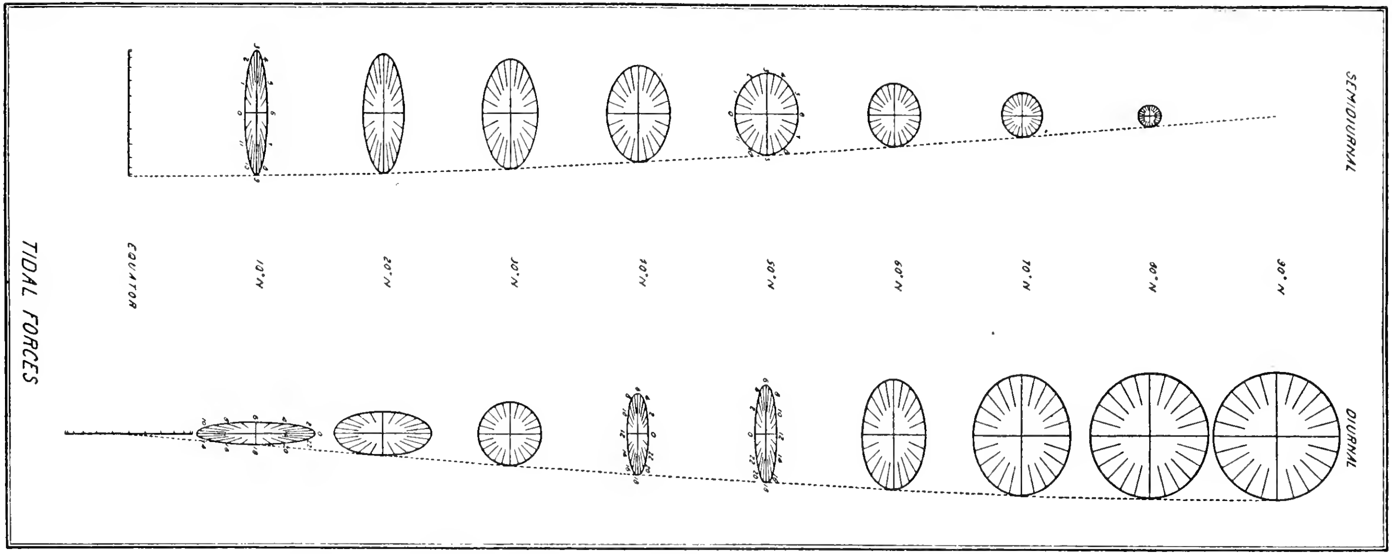

FIG. 1. The diagram shows the magnitude and direction of the tidal forces at each half lunar hour for various north latitudes. Such a force is represented by a line drawn from the center to the periphery of the ellipse having the given latitude. At the equator the mean value of the semi-diurnal force at 9 or 3 o'clock is equal to one thirteen-millionth part of the force of gravity at the earth's surface. The diurnal forces shown in the figure are those occurring upon the day when the moon's declination is greatest either north or south.

it is the difference between the moon's attraction upon the given unit mass and the moon's attraction upon the entire earth divided by the mass of the earth. Because the depths of the oceans are small in comparison with the length of the earth's radius, and because of the smallness of the tidal forces, only the horizontal components of such forces are effective in the production of tides; and so these may, without impropriety, be spoken of as the tidal forces.

The vertical forces alter the intensity of the earth's gravity upon the waters of the ocean in a way similar to the alteration which would be occasioned were the density of the waters to undergo a fluctuation having a range of less than one ten-millionth part of itself. Now the greatest known ocean depth occurs near Guam Island and measures 5,269 fathoms or 31,614 feet; and it is obvious that the small density fluctuation just mentioned, and so the vertical forces, can create no sensible disturbance in the existing ocean.

For simplicity's sake, we shall here ignore that alternation in the forces which depends upon the declination of the moon, and is responsible for what is called the "diurnal inequality" in the tides. We shall also, as a rule, ignore that portion of the tidal forces resulting from the sun's attraction.

It is evident that at moonrise or moonset at a given point or locality upon the earth's equator, the horizontal forces vanish because the given point is then (very nearly) as remote from the moon as is the earth's center. On account of the moon's parallax, the moon at the times of rise or set does exert a downward disturbing force at the given point or locality; but, as already stated, this does not concern the tides. When the moon is on the meridian above or below the horizon, the disturbing force is all vertical and so the horizontal component does not exist. Therefore the tidal forces vanish four times during each lunar day. From moonrise to moon culmination, the force is directed eastward; and from culmination to moonset, westward. Also from moonset to lower culmination, the force is directed eastward, and from lower culmination to moonrise, westward.

For a point not upon the equator, there is also a meridional periodic force. In north latitude this force has its maximum southward value at the time of either culmination, and its maximum northward value at moonrise and moonset. The reverse of this is true for a point situated in the southern hemisphere.

In accordance with what has been said, a suspended plumb bob will, at the equator, make two complete oscillations daily in an east-and-west direction. The average amount of deviation either way from its undisturbed position will be about one thirteen-millionth part of the length of the line measured from the point of suspension to the center of inertia of the bob.

EQUILIBRIUM OR LAKE TIDES

The surface of a small and sufficiently deep body of water will arrange itself normal to the direction of apparent gravity; that is, normal to the direction of terrestrial gravity when disturbed by the moon and sun, or, in other words, normal to the disturbed plumb line. If such a body of water be situated upon the earth's equator, high water will occur at its east end three lunar hours before the upper or lower culmination of the moon and low water, three hours after such times. When it is high watér at the east end, it will be low water at the west end, and *vice versâ.* The amount of the rise and fall (*i. e.,* the range of tide) at either end will be one thirteen-millionth part of the length of the body of water. If the body of water be not upon the equator, the range of tide will be somewhat less, and the times of high water around its margin will be progressive, following the order of the hands of a watch in the northern hemisphere and the opposite order in the southern. At the center of gravity of the surface of such a body will be a point having no rise and fall of tide, and so styled a "no-tide point." Tides produced in this way are called "equilibrium tides"; the minute tide found in Lake Superior constitutes an excellent example of this class. The observed rise and fall of the lunar tide at Duluth amounts to 1.6 inches, while the value computed directly from the forces amounts to 1.4 inches.

As commonly taught in schools and colleges, the expression "equilibrium tide" is used to denote a fluctuation in the ocean's surface resulting from an instantaneous arrangement of all water particles such that the surface of the ocean is everywhere apparently level, or normal to the direction of the earth's gravity when slightly disturbed by the action of the moon. It is taught that, but for the resistance caused by the continents and ocean bed, high water at a given place would occur when the moon crosses the local meridian. As may be gathered from what follows, this conception is fundamentally wrong. The semidaily fluctuation of the ocean's surface does not even approximate towards a surface of equilibrium, because the inertia of the water, and the shallowness of the ocean, when its depths are compared with its horizontal dimensions or with the distance from the surface to the center of the earth, prevent such adjustment from taking place in anything like the half-daily period.

OSCILLATORY OR OCEAN TIDES

Most tides are not equilibrium tides; they are waves either stationary or progressive. The forces just described act upon portions of the oceans which are susceptible of taking up stationary oscillations having about the same period as the period of the forces. In this way the dominant tides originate. But irregularities in depth and coast line, particularly openings through the latter, cause the tides generated in these ocean basins to send off progressive waves into other parts of the oceans and into seas, gulfs, bays and tidal rivers.

By a stationary oscillation is meant a mode of motion which can be readily set up and maintained in a tank, vase or other artificial vessel of water. High water at one end of a rectangular body of water occurs when it is low water at the other end, if the simplest mode of oscillation be under consideration. Between the two ends is a line, styled "nodal line," along which there is neither rise nor fall but across which the horizontal motion of the liquid particles is comparatively great. In order that a large and regular oscillation may be maintained, it is necessary that the natural period of the basin of water be very nearly equal to the period of the applied forces: just as a resonator must have certain dimensions if a particular musical tone is to be reinforced by its presence. An oscillation is best sustained if the phases (or time-angles) of the forces, all parts of the system being considered, agree, as well as may be, with the phases of the velocities of the water particles. This furnishes a clue to the times of the tides when one knows the times of the vanishing of the forces.

Obviously, if two rectangular basins performing simultaneous oscillations in accordance with their simplest modes be put together end-to-end, and the partition between them removed, the whole body may be made to so oscillate that high water will occur simultaneously at the two ends, while it will be low water over the central portion. The nodal lines will remain in the same positions as before, crossing the individual bodies midway between their real and virtual ends, or the new body at points one quarter of the body's length from either end. The individual bodies each comprise a half wave-length of the whole-wave system to which they now belong. The oscillation in each of the individual bodies is said to be "uninodal" and that in the whole body, "binodal."

No-tide Points

Points shown upon the charts (Figs. 5, 6 and 7) from which the cotidal lines radiate, are no-tide points; that is, points at each of which there is no rise and fall of tide. In the oceans these points are due to the fact that the times of the tides around them and which times are dependent upon stationary or progressive waves, or both, must take successively all values from one to twelve, because in open water sudden changes in time can not occur.

In narrow arms of the sea, no-tide points may result from dependent stationary oscillations influenced by the deflecting force of the earth's rotation. This, for the northern hemisphere, is such that if we always face the direction towards which the flood or ebb stream is flowing, water will be piled up upon the side of the channel then situated upon the right, and drawn away from the opposite bank. The reverse of this occurs for channels situated in south latitude.

ATLANTIC-OCEAN TIDES

A body of water resembling the artificial one just described is the portion of the Atlantic Ocean (shown by one form of shading) extending from South America to southern Greenland and resting against the western coast of Africa and Europe. A section of this basin or system is shown by means of a diagram (Fig. 2). One nodal line passes near the Cape Verde Islands and another lies westerly from Ireland. When it is high water on the coasts of Guiana and Brazil, it is also high water around southern Greenland, and it is then low water along the coast of Morocco, Spain and Portugal. The Roman numerals upon the small map of the world show that high water occurs at eight o'clock, Greenwich lunar time, for the South American and Greenland ends of this basin and at two o'clock for the central or Morocco portion. On account of the extensive openings to the eastward and northward of this basin or system, progressive waves are formed which contribute to the tides around the British Isles and Arctic Archipelago, and are chiefly responsible for the tides of the Arctic Ocean. Since progressive waves can not arise suddenly, their effects are felt over a large portion of the system now under consideration, and they tend to obscure the theoretical nodal lines which cross it.

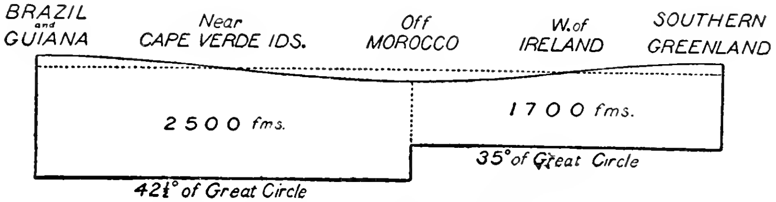

FIG. 2. This diagram shows the binodal oscillation going on in the North Atlantic Ocean. When it is high water at either end, it is low water off Morocco and *vice versâ*. The depth of the southern portion being greater than the depth of the northern, a half wave-length in the former exceeds a half wave-length in the latter—the period in each case being very nearly 12 lunar hours.

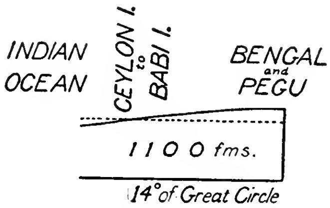

FIG. 3. This diagram shows that the Bay of Bengal measures a quarter of a wave-length to its nodal line extending eastward from Ceylon. Its tide depends directly upon that tide of the Indian Ocean which lies to the southward of the nodal line.

The tides along the Atlantic Coast of the United States are produced in the body of water which extends from this coast to the Antarctic Continent by way of Cape of Good Hope. This is shown upon the smaller chart of the world (Fig. 4) by one of the types of shading. The northern portion of this region is not greatly influenced by progressive waves because the openings through its northwestern, or United-States, boundary are not large. Consequently, the theoretical nodal line running northeasterly from the Lesser Antilles is not obscured. Referring now to the cotidal chart of the Atlantic Ocean (Fig. 5), it will be seen that the mean range of tide, as shown by Arabic numerals, is seven feet along the coast of Georgia, between two and three feet for the Bahamas, one foot for the outer coast of Porto Rico, and little or nothing some leagues farther eastward. Hence the observational proof of the existence of one end of this nodal line.

When it is high water along the Atlantic Coast of the United States, it should be low water between Brazil and western Africa; that is, because the tidal hour is twelve for the former locality, it should be six for the latter. Doubtless such is the case for the portion of the tide depending upon the system now under consideration. But the system previously considered, viz., that extending from Guiana and Brazil to southern Greenland, gives eight for the tidal hour off the Brazilian coast. This explains why the observed times of tide between western Africa and Brazil fall between six and eight o'clock.

All along the southeastern coast of Brazil, the tidal hour is six, while west of Cape of Good Hope it is about twelve—but not exactly twelve because this locality is influenced by a progressive wave due to the existence of the Gulf of Guinea.

Farther south, along the Antarctic Continent, the tidal hour is doubtless six, but no observations are available for verifying this conclusion.

It may be noted here, and before going farther, that upon the small chart of the world (Fig. 4), the unshaded water areas are such that forces acting upon them, and them alone, can produce little tide either in such areas themselves or in other parts of the oceans. In other words, if they possess tides, these will depend upon the tides existing in such portions of the oceans as are comparatively well suited for their production. Heavy lines upon the chart indicate outer boundaries of systems. If rigid walls were erected along the outer boundaries of any particular system, the forces would incite tides of considerable size in the waters bounded by the walls and the shore lines; the tides of the system, if kept down by resistance, would nearly agree in their times of occurrence with the tides actually existing. These hypothetical bodies of water, together with such landward dependencies as have their tides occurring simultaneously with those of the body proper and upon which the forces act, are shaded by means of light parallel lines. In a particular ocean, the systems are distinguished by the directions given to the lines of shading. Double shading indicates an overlapping of systems.

The waters surrounding the British Isles have, as a rule, large tides accompanied by swift tidal streams. They depend chiefly upon the rise and fall of that part of the ocean situated to the southwestward of these isles.

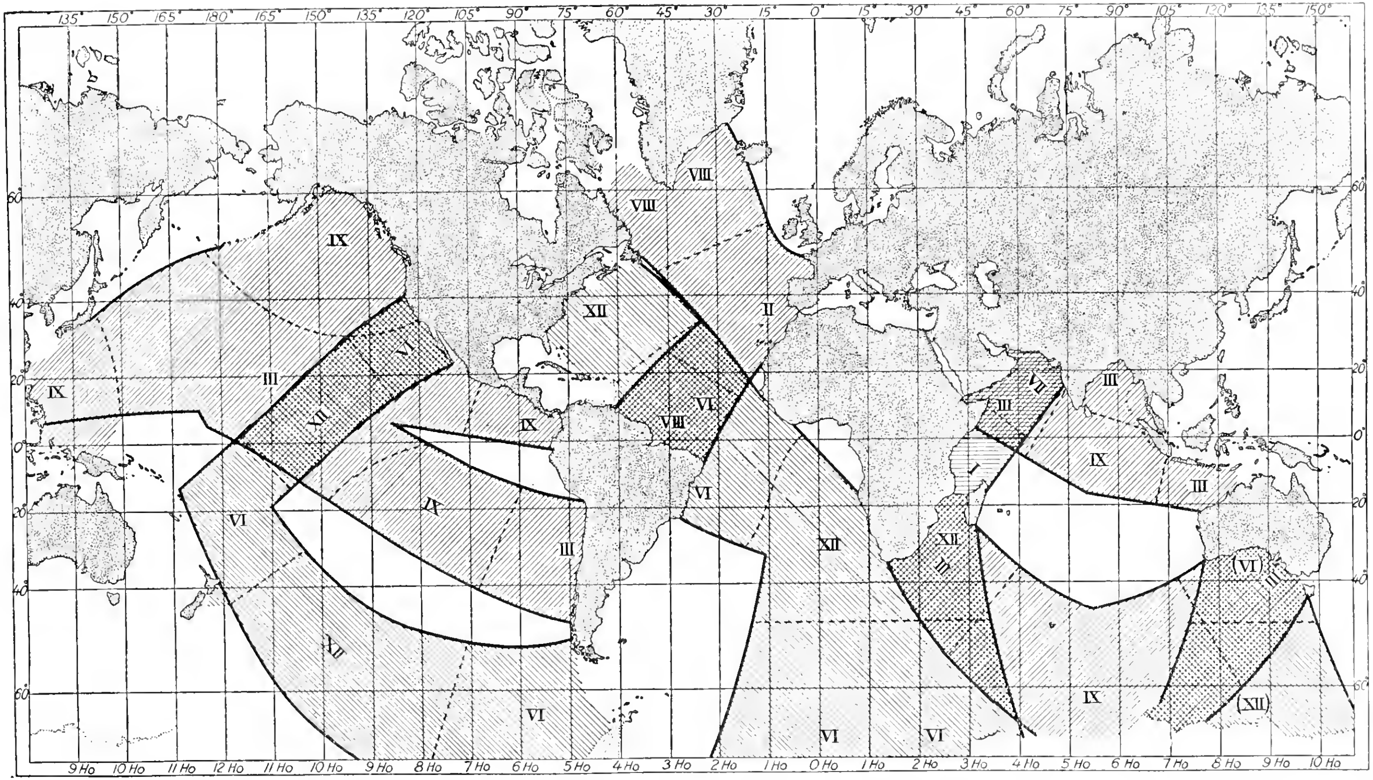

FIG. 4. Systems for the Semi-daily Tides. The shaded portions of this chart represent the regions most concerned in the production of tides, together with landward dependencies which possess tides simultaneous with those of the systems proper. The Roman numerals refer to Greenwich lunar time of high water. The values upon Fig. 4 are nearly those which would result from theoretical considerations. The values upon Figs. 5, 6, 7 and 8 are made to agree with observation as nearly as possible. The Arabic numerals on Figs. 5, 6, 7 and 8 denote mean ranges in feet of the observed semi-daily tide. The Roman numerals are placed upon that side of a cotidal line towards which the wave appears to progress.

The diminution of the mean range of tide in going westward from Portugal indicates the existence of a no-tide point westward from the Azores. Other no-tide points occur in European and American arms of the Atlantic Ocean. The no-tide point between Holland and England was first pointed out by Dr. Whewell and the one in the Adriatic Sea by Dr. Sterneck.

INDIAN-OCEAN TIDES

The Indian Ocean contains two strips of water well suited to the production of tides. The first extends from the northwestern coast of Australia to the coast of Somali Land and Arabia, the second, from the southern coast of Australia to the southern coast of Africa and Madagascar—the southern edge of this strip resting upon the Antarctic Continent. The tides of the Bay of Bengal depend upon those generated in the first strip, while the horizontal shading in the area between Madagascar and Hindustan, taken in connection with the tidal hours, indicates that an oscillation exists in this area which depends chiefly upon the rise and fall of the tide at the southern end of Mozambique Channel.

The stationary character of the tide in the Bay of Bengal is shown not only upon the small chart of the world, but also upon the chart of cotidal lines which covers the Indian Ocean (Fig. 6). A vertical section is shown by means of a diagram (Fig. 3).

The distance southward from the southern coast of Australia to the Antarctic Continent is less than a half wave-length of the lunar tide. It is more nearly equal to a half wave-length of the solar tide. Consequently the tides due to this oscillation are chiefly solar, and the tidal hours are enclosed in parentheses for the sake of distinction.

Fig. 6 shows that a great diversity of ranges of tide occurs in the Indian Ocean. Between Ceylon and Sumatra the mean range of tide is about one foot, while at the head of the Gulf of Martaban the range is nearly 14 feet. In the mouths of the Ganges the mean range is nearly 10 feet. At the southern extremity of Hindustan Peninsula the mean range of tide is about 1.5 feet while at the head of the Gulf of Cambay it is 23 feet. On the western coast of Madagascar the range of tide is 8 or 10 feet, while at Tamatave, upon the eastern coast, it is 1.5 feet. At Freemantle, near the southwestern corner of Australia, the range of the semidaily tide is 0.4 foot, while at Collier Bay and King Sound on the northwestern coast the mean range of tide is about 24 feet.

Between Madagascar and Hindustan is a no-tide point where the rise and fall of the semidaily tide vanishes.

PACIFIC-OCEAN TIDES

The tides in the Pacific Ocean are produced by two systems of oscillations which are distinguished from each other by the two kinds of

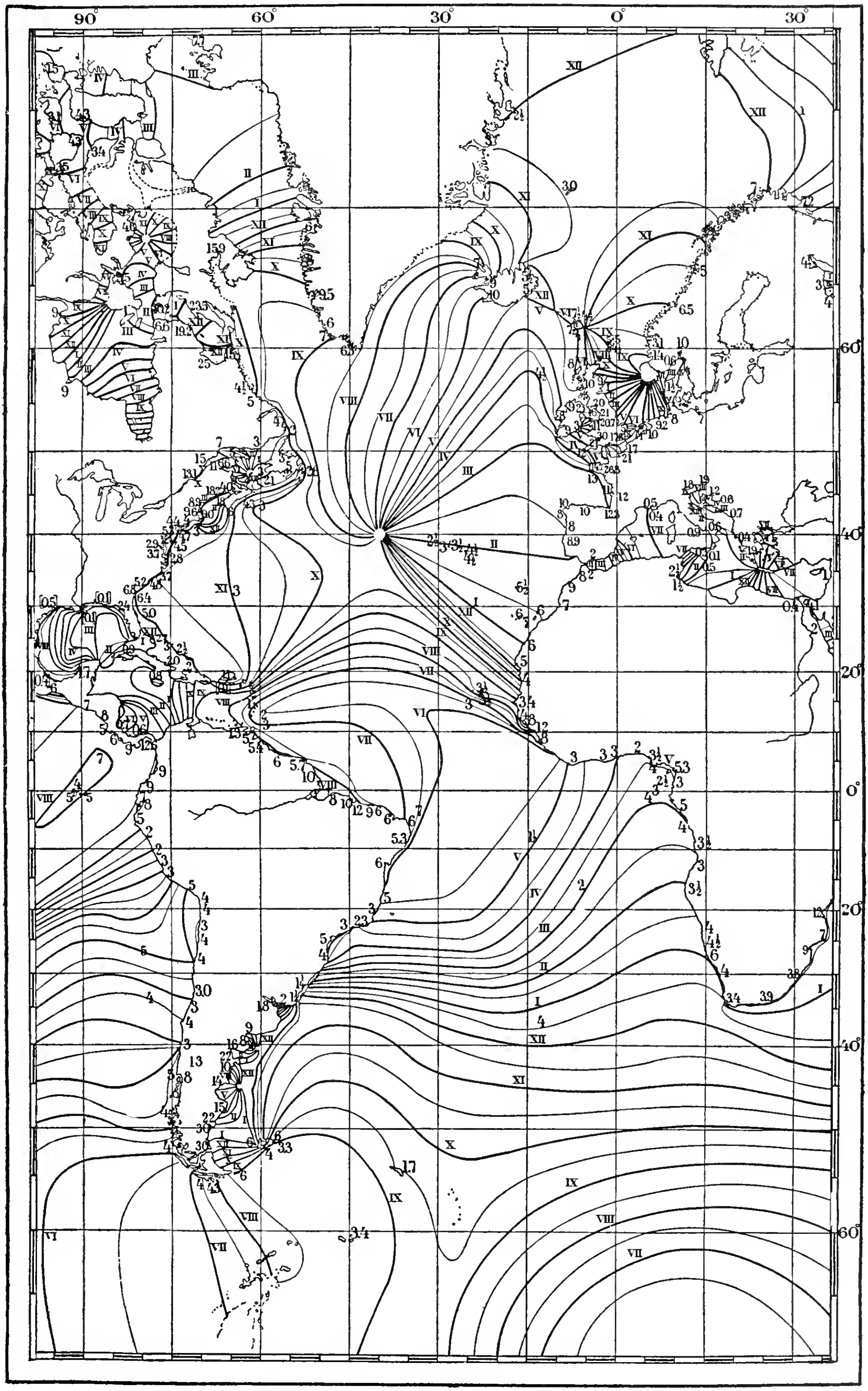

Fig. 5.

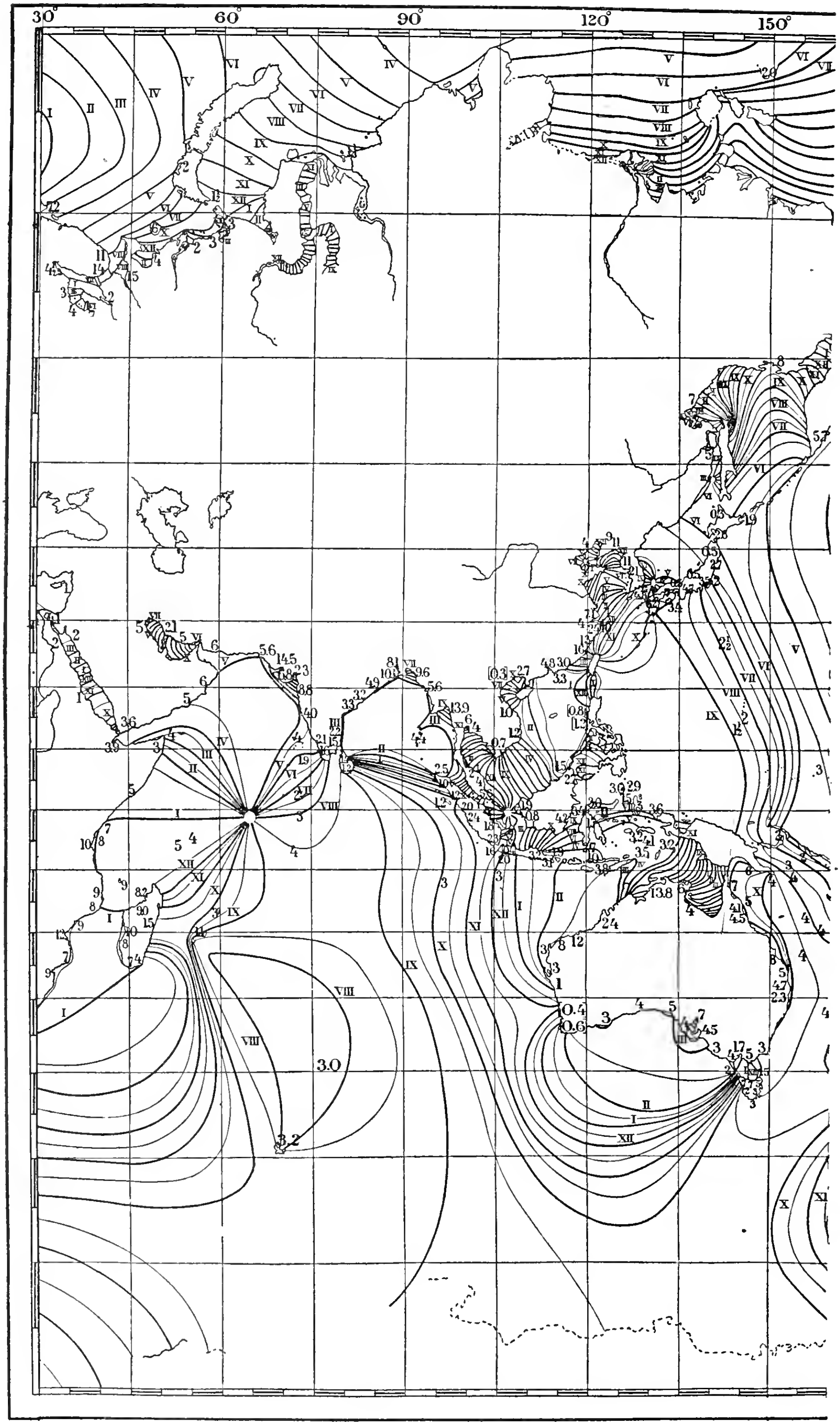

Fig. 6.

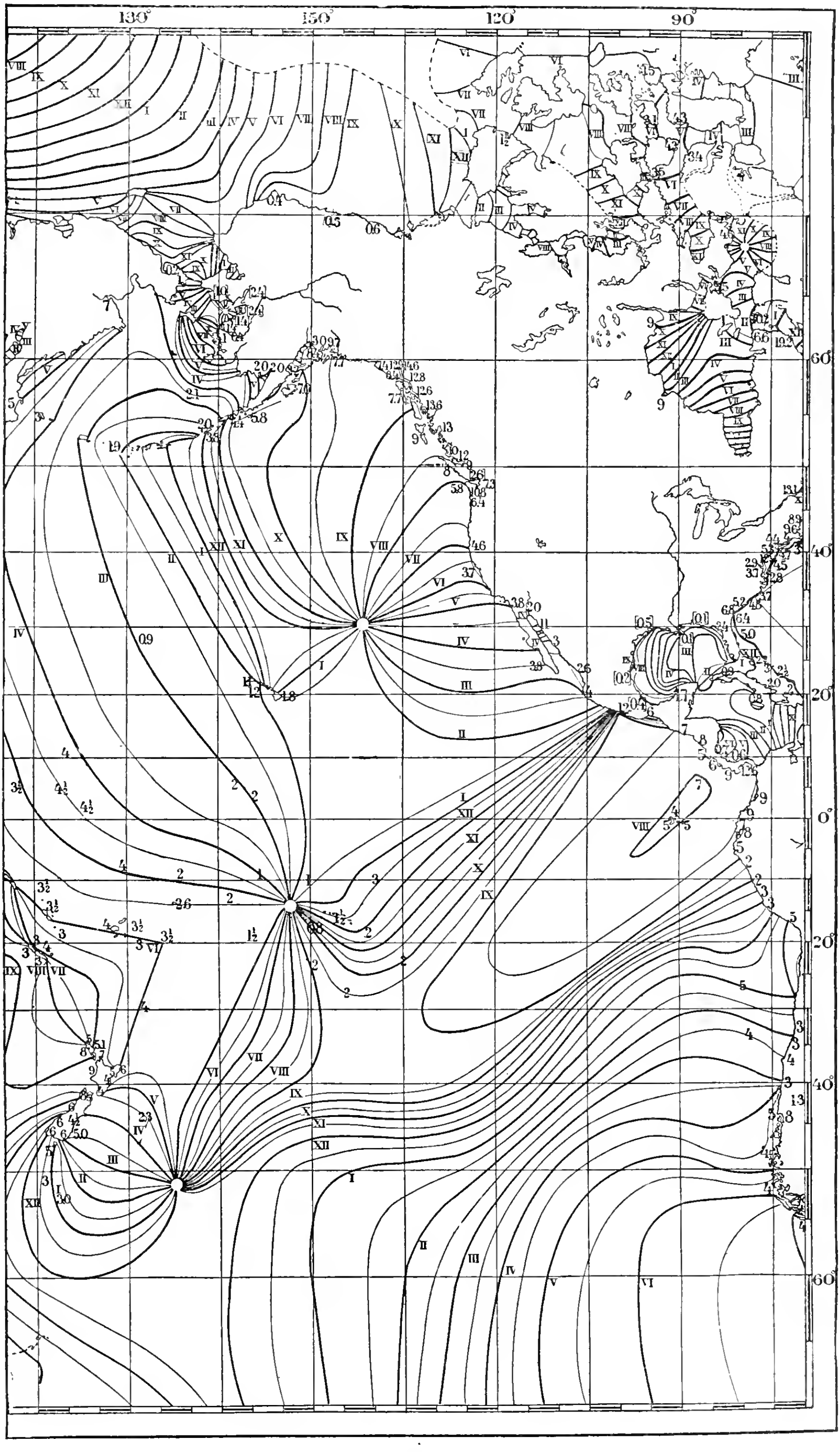

FIG. 7.

shading (Fig. 4). The region occupied by the first comprises a triangular body of water covering the greater portion of the North Pacific Ocean, and also a trapezoidal body extending in a southeasterly direction to the coast of Chile. The nodal line near Acapulco, Mexico, is

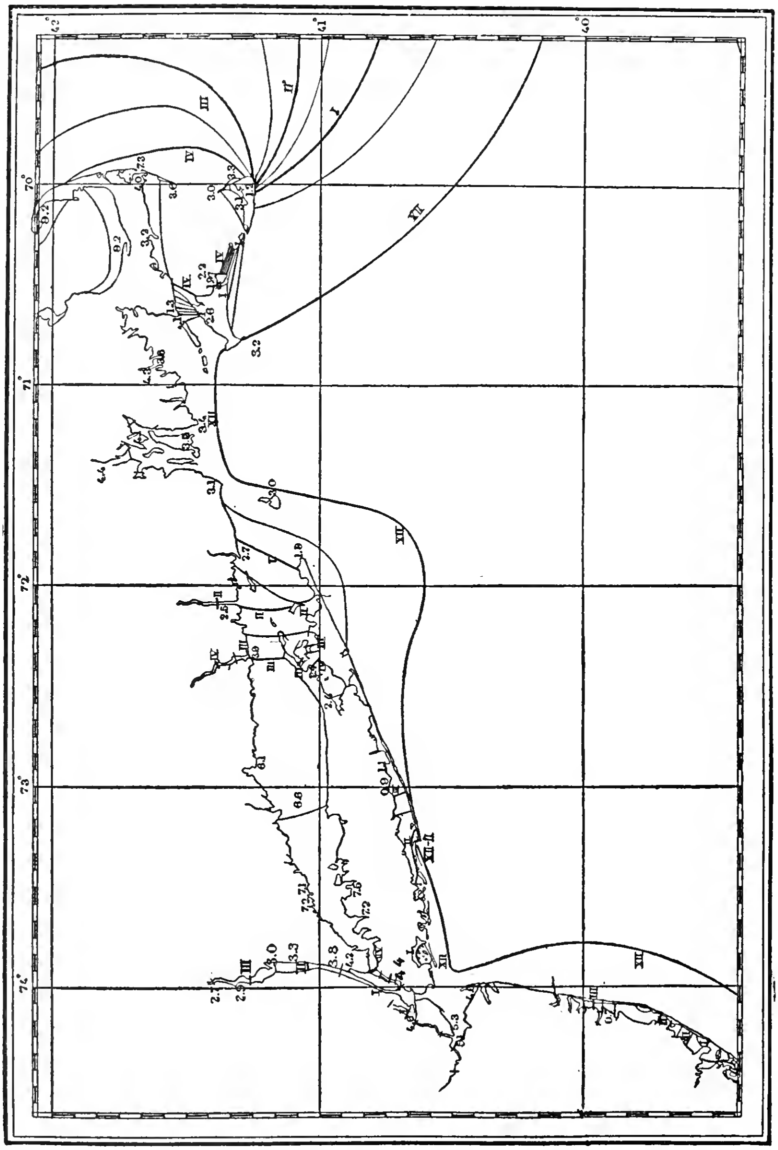

Fig. 8. Cotidal lines for New York Harbor and approaches.

very apparent from observation, as can be seen upon consulting the chart of cotidal lines for the Pacific Ocean (Fig. 7). The same chart shows the stationary character of the oscillation by the fact that at the three angles of this huge triangle—that is, in Panama Bay, the Gulf of Alaska and off the coast of Luzon—the tide occurs at nearly one and the same time, while the amount of rise and fall is considerable. Also, that for a considerable area around each of these angles, the time of tide changes slowly in going from place to place. The range of tide gradually decreases from the Gulf of Alaska, where it is about eight feet, to the western groups of the Aleutian Islands—the range off Rat Islands being less than two feet.

The South Pacific system embraces an L-shaped region extending from the coast of California and Lower California to the shoals and islands north of New Zealand, thence southeasterly to southern Chile and Graham Land.

Three no-tide points occur in mid-ocean, one occurs in Norton Sound, Alaska, one near either end of the Sea of Japan, and one in the Gulf of Pechili.

Tides at the Isthmus of Panama and Elsewhere

Referring now to the cotidal maps of the world, it appears that the mean range of tide at Panama is 12.6 feet, while at Colon, just across the isthmus, it is only 0.6 foot. That a great difference between the tides at these two points exists was mentioned by Oviedo y Valdez as long ago as 1526, and the question as to the reasons therefor has been frequently raised even up to the present time. Upon consulting the small chart of the world, it will be seen that Panama is situated at one angle of the triangular area where the rise and fall would naturally be greatest.

On the other hand, the tides which enter the Caribbean Sea from the ocean must be small because of the proximity of the nodal line setting out from the Lesser Antilles (Fig. 4). The time and range of the small tide at Colon indicate that it belongs to the equilibrium tides of the Caribbean Sea itself.

Likewise the small tides in the southwestern portion of the Gulf of Mexico are equilibrium tides belonging to the gulf.

The tides in the eastern portion of the Mediterranean are equilibrium tides of that body.

The tides in the Red Sea consist partly of a bodily oscillation of that sea and partly of a progressive wave from the Indian Ocean.

The tides found along the South American coast, from Cape Horn to Rio de la Plata, are derived from the tides of the Pacific Ocean, as is apparent from the chart of cotidal lines for the Atlantic Ocean. The range of tide is about thirty feet at the eastern end of Magellan Strait and less than two feet at Buenos Aires.

Dependent Stationary Wave

It has already been noted that a dependent stationary wave occupies the Bay of Bengal. Such waves are found in the following arms of the sea: The English Channel; the Irish Sea; the Adriatic Sea; the Gulf of St. Lawrence; the Gulf of Maine, including the Bay of Fundy; Long Island Sound; Bahia Grande; the Gulf of California; the Gulf of Georgia; and Norton Sound. These waves are accompanied by progressive waves, setting inwardly; and the effects of the deflecting force of the earth's rotation upon the moving waters are generally more or less apparent. As a consequence, nodal lines, such as characterize simple stationary waves, are more or less concealed in the bodies of water just mentioned.

Tides in the Vicinity of New York

Turning now to the chart of cotidal lines for New York Harbor and approaches (Fig. 8), several items may be noted:

The tidal hour changes rapidly along the southeastern coast of Nantucket Island. Here the range of tide is small. Over Cape Cod Bay the time of tide is simultaneous, and the mean range exceeds nine feet. Through Muskeget Channel the tidal hour changes rapidly and the currents are hydraulic in character; *i. e.*, the flood and ebb are not oscillatory, but simply flow towards the body of water which is temporarily the lower. A similar remark is approximately true for Vineyard Sound. Over Buzzards Bay the tide is nearly simultaneous, indicating the stationary character of the tide wave. A similar remark is approximately true for Narragansett Bay.

The proposed Cape Cod Ship Canal will connect the waters of Cape Cod Bay at a locality where the average rise and fall of the tide is nearly ten feet with those of Buzzards Bay, where the average range scarcely exceeds four feet. The difference in level due to the tides will suffice to produce in this canal, a tidal current having an ordinary maximum velocity of three knots per hour.

In the eastern portion of Long Island Sound the time of tide changes rapidly and the range of tide is small. Over the greater portion of the Sound the tide is nearly simultaneous; and the mean range exceeds seven feet at the western end. The time and range of tide change rapidly through East River, and the tidal currents are hydraulic and strong. West of the northern end of Blackwells Island, the ordinary maximum velocity is five knots. Before the Hell Gate channel was cleared of reefs and submerged rocks, the currents were a source of much inconvenience and danger to all shipping passing through the East River. The time and range of tide change rapidly in Fire Island Inlet, and the tidal currents are hydraulic and strong. A similar remark is true for Barnegat Inlet. The tide in Raritan Bay consists chiefly of a stationary wave. The tidal currents in Arthur Kill and Kill van Kull are nearly hydraulic. The tide in the Hudson River consists chiefly of a progressive wave.

Attention has been called to these local details for the purpose of showing how varied the tidal phenomena may be within a comparatively limited region, and that detailed cotidal maps can be constructed with accuracy only after tidal observations have been made at a great number of points along the shores and upon the islands included in the area to be represented. The gauging of the tide away from land has seldom been undertaken; but there are indications that in the future such work will be carried out on an extensive scale.

CONCLUDING REMARKS

From the cotidal maps of the world, the reader can draw his own conclusions concerning the resemblance between the tides as they must approximately occur in nature and the hypothetical tides progressing westerly around the globe according to the popular conception of to-day and which, as we have seen, existed at the time when the Ptolemaic System held sway over the astronomy of mediæval times. He will find no indications of tide waves having crests coincident with meridians and progressing westward at the rate of fifteen degrees of longitude per lunar hour. He will see that even a general westerly progression of the tide around the globe has no existence in fact.

The dictum of Aristotle, Pliny, Newton and others, that large tides are found in large seas, can be tested by means of these charts. The truth of this is manifest when the tides of the Mediterranean Sea are compared with those of the North Atlantic Ocean, but no such rule applies when the tides of the North Atlantic Ocean are compared with those of the Pacific Ocean and especially with those of the South Pacific Ocean.

The reader may ask, How does it happen that even rude approximations to the tides in nature have been so slow in their development? The answer is, Definite or applicable theories concerning the causes of existing tides were impossible before the depths of the oceans had become generally known. And so, before a few decades ago, tidal theories were developed with reference to certain assumed or hypothetical cases. This remark is no disparagement of the labors of such men as Newton, Laplace and Airy, and which compel the admiration of all persons interested in tidal matters. In fact, the comparative simplicity of the hypotheses upon which their theories were founded, placed tidal work squarely upon a scientific basis and enabled these intellectual giants to press their investigations a long way towards completion.

As to the construction of cotidal lines for the various oceans, it may be said that this implies, not only a rational approximate theory, but also a multitude of carefully-made tidal observations; such observations are, even to-day, either wanting or defective in many portions of the globe despite the efforts of individuals, expeditions, learned societies, institutions and governments.

FACTS CONCERNING THE DETERMINATION AND INHERITANCE OF SEX

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SINCE the time of Aristotle numerous observations have been recorded concerning the phenomenon of sex. Long prior to this period, undoubtedly, men were vexed by such questions as: Why in the same litter of animals are some male and others female? Why in the same brood of chickens do some develop into hens and others into cocks? Why in the same family are some of the children girls and others boys? What determines that one animal or plant shall be male and another female? When does the sex of the organism become unalterably fixed? What is the nature of sex? A great deal of light has been recently thrown upon all these questions. In modern times a solution is being attempted by refined scientific means. Statistical, experimental and cytological methods of research are being employed. The fogs of mystery enshrouding the phenomenon of sex are becoming more and more attenuated and we may confidently hope soon to see them cleared away. Much has lately been discovered that strongly indicates the probable answer to the foregoing questions. Moreover, in their attempts to elucidate the enigmas of sex, men have been actuated as much by a pure scientific motive of love of truth as by the practical bearing of completer knowledge respecting sex-determination on the matter of the control and regulation of sex. The two main problems involved concern the *time when* sex is determined and the *means by which* such determination is established.

Aristotle had noted in the case of pigeons that of two eggs laid in each batch, one generally produced a male and the other a female. He further reported that the first gave rise to the male and the second to the female. Flourens has confirmed this fact for eleven sets of eggs and Cuénot has more recently obtained the same result. What is the meaning of this fact? Aristotle speculated and men are still speculating. When Drelincourt wrote regarding the matter of sex in the eighteenth century he gathered together two hundred and sixty-two theories and hypotheses concerning the nature and cause of sex and declared them all "groundless." Blumenbach subsequently contributed another and reported two hundred and sixty-three worthless theories, having added Drelincourt's to the list. Since then the number of theories not well founded on actual facts has increased to more than five hundred. The great majority of these are largely unscientific, the result mostly of philosophical speculation or *a priori* opinion. As examples of such it was supposed that an egg from the right ovary gave rise to a male and an egg from the left ovary to a female; that the sex of the offspring was like that of the younger or more superior parent; the exact opposite of the latter, that the sex was that of the weaker or older parent; or that the younger or more vigorous parent determined the opposite sex in the offspring; and many others involving equally off-hand assumptions. That the sex of the offspring is that of the weaker parent has been recently advocated again and statistically apparently well supported by Dr. Romme, a well-known physiologist of London. In further support of his theory he cites the fact that among barbarous nations continually at war there is always a preponderance of boys over girls.

Professor Schenck's famous sex-theory is in essence the same. He proposes to increase the physical vigor and the number of the red blood corpuscles in a person when it is the wish to beget a child of the opposite sex. Renewed interest has been aroused in this theory, due to Professor Schenck's connection with the royal family of Russia, where he put his principle to the test with an apparently successful result when the Czarina gave birth to the desired son. But Professor Simon Newcomb, as the result of a very extensive statistical investigation, concludes that "it seems in the highest degree unlikely that there is any way by which a parent can affect the sex of his or her offspring."

Within the last decade students of the problem of sex have become very generally agreed that sex is inherited. In other words, they believe that the same mechanism that provides that an offspring shall have one or the other of a pair of contrasting characters represented in the two parents (a long sharp nose or a short stubby nose, for example) provides also that the animal shall have either the sex of the mother or that of the father. The problem of sex seems to be part and parcel with the general problem of inheritance. Furthermore, characters of the parents are believed to be inherited by the offspring according to Mendelian principles. And it can be shown, as was done by Dr. Castle, of Harvard University, in 1903, that sex may be regarded as the result of a Mendelian segregation, dominance and inheritance of sexual characters. And now it becomes incumbent to explain Mendelian inheritance before continuing the discussion of the problem of sex, seeing that sex appears to be inherited in Mendelian fashion.

Mendelism is the term employed to designate a set of phenomena that appear when animals or plants with sharply contrasting characters (white flower petals and colored petals; gray fur and white fur; short stature and long stature; sagacity and stupidity; etc.) are crossed. The principles included under the term Mendelism were first discovered by Gregor Mendel, abbot of Brünn, in 1866. Since then our knowledge of Mendelian inheritance has been greatly extended through the researches notably of Professor de Vries, of Amsterdam; Professor Bateson and Professor Punnett, of Cambridge University, England; Professor Cuénot, of Paris; Professor Castle, of Harvard University; Dr. Davenport, of the Station of Experimental Evolution of the Carnegie Institution at Cold Spring Harbor, Long Island, and Professor Morgan, of Columbia University. For the purpose of elucidating this subject in respect to its essential principles and its peculiar nomenclature we will take the simple case of two varieties of pea, one with seed colored yellow and the other with seed colored green. These are said to be "pure" in the sense that from green seed-bearing individuals when interbred only green seed-bearing plants will arise, and from yellow peas only yellow seed-bearing plants. In order that plants or animals may be successfully crossed it is requisite that they be closely related species or varieties.

Mendel found at the beginning of his work that when a cross is made between two such varieties of peas, the first succeeding generation yields peas that are all colored yellow. When flowers from plants of the latter are self-pollinated, *i. e.,* crossed with their own kind, there result peas of two kinds, yellow and green, and the proportion of such seed is three of the former to one of the latter. This means that the yellow color is "dominant" over the green color, which is said to be "recessive." Mendel further discovered that when the green recessives were self-pollinated their seed always produced only green seed-bearing plants. Such were called "pure recessives" or "extracted recessives." He found also that among the 75 per cent. of yellow seed 25 per cent. always bred true, *i. e.,* they gave rise to only yellow seed-bearing plants. Such were designated "pure" or "extracted dominants." But the remaining 50 per cent. on self-fertilization again yielded peas in the proportion of 75 per cent. yellows to 25 per cent. pure recessive greens. The Mendelian proportion then in the case where a single set of contrasting characters ("unit characters" or pair of "allelomorphs") are crossed is 25 per cent. pure dominants (yellow in color); 50 per cent. color hybrids (also yellow in color, since yellow dominates over green); and 25 per cent. pure recessives (green in color).

Mendel explained the foregoing facts on the assumption that during the process of maturation, when the unripe cells divide each into four mature germ-cells, eggs or pollen grains (ova or spermatozoa in animals), the carriers of the qualities yellow and green are segregated into different cells. In other words, no eggs or pollen grains (sperms) carry both characters, but only one or the other character. Accordingly, among the eggs 50 per cent. carry the quality yellow and 50 per cent. carry the quality green; among the pollen grains 50 per cent. again carry only the yellow color and 50 per cent. the green. At fertilization eggs and pollen grains meet fortuitously and according to the laws of chance there are twice as many possibilities that an egg with a green color-determinant (G) shall meet a pollen grain with a yellow color-determinant (Y), and *vice versa,* as that an egg with a green determinant shall meet a pollen grain with a green determinant, or that an egg with a yellow determinant shall meet a pollen grain with a yellow determinant. Hence the combinations produced may be expressed thus: 1YY: 2YG: 1GG. Among the seed 50 per cent. are hybrids in respect to color, but since the yellow color dominates over the green all appear yellow, giving a total of 75 per cent. yellow peas and 25 per cent. green peas.

When pure strains of sweet peas with white flowers are crossed with pure-bred peas with red flowers similar results follow. All the plants of the first generation bear red flowers, showing the dominance of red color over white color. When these are interbred the plants of the second generation split up in the proportion of 75 per cent. red-flower-bearing to 25 per cent. white-flower-bearing; or 25 per cent. will be red pure dominants, 50 per cent. red hybrids and 25 per cent. white pure recessives. Also when white mice (albinos) are crossed with gray mice (or pigmented mice) the first generation are all gray, when the latter are bred among themselves the second generation includes albinos and gray individuals in the proportion of 1 pure gray: 2 gray hybrids: 1 pure white.

In applying Mendelian principles to sex, maleness and femaleness are regarded as unit characters and during the maturation of the germ-cells the carriers (chromosomal elements) of the male and female qualities are believed to be segregated in different cells, both ova and spermatozoa, so that one half of the ova contain the male-determining factor and the other half the female; and likewise the spermatozoa. The result of a fortuitous intermingling of ova and sperm, according to strict Mendelian laws, should produce male and female individuals in the proportion of 3:1 or the reverse. Suppose femaleness dominated, then there would be 75 females in every 100 of population or of any particular species. No such disproportion of sexes obtains. In fact, barring a few exceptions which may be explained as adaptations or as the result of a selective mortality, all species are approximately equally divided into two classes with respect to sex. Further assumptions must be made and pure Mendelism modified. The obvious and necessary assumptions are that there are no individuals pure in sex; all are hybrids; and the sex that the organism attains is the result of a struggle between the mingled male and female tendencies and the dominance, now of one tendency, now of the other. The dominance may be due, as Dr. Thomson, of the University of Aberdeen, suggests, to slight metabolic fluctuations, now in favor of maleness (katabolic), now in favor of femaleness (anabolic), the net result being an approximately equal proportion of males to females. In other words, there must be selective fertilization, that is, a female ovum must be fertilized by a male sperm, and *vice versa.* The various assumptions made are not pure speculations, but rest upon many facts. Some animals do possess two kinds of eggs, of which one (the larger) develops into females and the other kind (the smaller) into males; there are many instances of selective fertilization; and many animals do produce two kinds of spermatozoa.

If there is only one kind of egg, as Correns suggests—as may well be the case, since of the four potential ova, three (the polar bodies) degenerate during maturation and only one becomes capable of fertilization—and two kinds of spermatozoa, the explanation of sex becomes very much simpler. One sex (female) must then be pure in respect to sex (a homozygote) and the other must be a sex-hybrid (heterozygote). If the egg is female in tendency, in order that there should appear 50 per cent. males, maleness must dominate over femaleness. In any case, an interpretation of the facts involves the application of some phase of Mendelism. As will appear farther on, the case of the honey-bee, ants and plant-lice offer serious obstacles to the universal application of Correns's interpretation, and even of the whole Mendelian scheme.

Within the last decade three main positions have been advocated by various investigators in regard to the cause of sex. The position held by Beard and his school is to the effect that there are two kinds of eggs, male and female, and one kind of spermatozoa; and that sex is determined exclusively by the egg, the spermatozoon having no rôle in sex production. This position can be supported by various facts. A certain worm (*Dinophilus apatris*) carefully studied by Korschelt, is known to produce two kinds of eggs, large and small, the former developing into females, the latter into males. Of course it might be urged that in consequence of selective fertilization only the small eggs are impregnated by a male-producing spermatozoan and the large eggs by a female-producing, and an entirely different interpretation of the facts would be necessitated. But in the case of *Hydatina senta,* a rotifer or "wheel animalcule," where large and small eggs are also laid, the former without fertilization develop into females and the latter into males. However, both kinds of females, the large-egg-laying kind and the small-egg-laying kind, came originally from fertilized eggs, and it may be that a difference in metabolic activity of the several females kept the eggs of the one small and allowed those of another to grow large and so gave the victory to the female determinant in the well-nourished egg. This assumption is supported by the fact that the amount of nourishment taken by the young female between the time of emergence from the egg and deposition of her first egg determines which kind of egg she shall subsequently produce. The well-nourished females produce female eggs, the poorly nourished produce male eggs. Sex, however, is determined while the ovum is still in the ovary. When the eggs have once been formed no subsequent change of food or temperature can alter the kind of eggs that are produced. *Phylloxera vitifola,* the plant louse that lives on the roots of the grapevine, also produces large and small eggs, developing parthenogenetically (without fertilization) into females and males, respectively.

The second position is that taken by Strasburger, Castle, Wilson and others who have derived their facts largely from the group of insects. These investigators are inclined to believe that there are two kinds of eggs as there are two kinds of spermatozoa, and that sex is the outcome of an interplay or struggle of the sex determinants of these elements and the dominance of one or the other sex. According to these biologists all animals are sex-hybrids; either sex is potentially present originally, but by reason of the dominance of one or the other sex-determinant the particular sex becomes patent and makes the animal definitively male or female. Dominance may be due, in many cases, as is indicated by some of the Hemiptera, to the presence of one or several extra and specific chromosomes—"idiochromosomes," "X-element" (Wilson). According to this view fertilization is selective, *i. e.,* a female egg is fertilized only by a male sperm, and *vice versa.* There are many observations and ascertained facts to support this position.

The case of the large "walking-stick" insect (*Aplopus mayeri*) or "devil's riding horse" of Loggerhead Key, Dry Tortugas, Florida, which I studied in 1907, illustrates the position under discussion. Similar facts had been reported previously for many insects by various American cytologists, notably Professor McClung, of the University of Kansas; Professor Montgomery, of the University of Pennsylvania, and Professor E. B. Wilson, of Columbia University. *Aplopus mayeri* (named after Dr. A. G. Mayer, director of the Biological Laboratory of the Carnegie Institution of Washington at Dry Tortugas, Florida) produces two kinds of spermatozoa differing in the number of chromosomes (rod-like bodies supposed to be the vehicles of the hereditary qualities) that the two classes possess. One half of the spermatozoa hold 17 chromosomes and the other half 18, the additional one being large and V-shaped (called by McClung the "accessory chromosome"). The somatic cells of the male contain 35 chromosomes, the somatic cells of the female, 36 chromosomes. When the eggs mature, the 36 chromosomes are reduced, by fusion in pairs and a subsequent double division, to 18 chromosomes. Now at fertilization when an egg of 18 chromosomes unites with a spermatozoan of 18 chromosomes an organism whose cells contain 36 chromosomes results, and this is a female;

when the other combination occurs, 18 chromosomes from egg and 17 chromosomes from sperm, an organism results that has only 35 chromosomes, and this is a male. It seems, therefore, as if the accessory chromosome was a sex-determinant in some sense—probably only in the sense of a visible accompaniment of some hidden underlying physiological cause of sex—perhaps as the carrier of a specific enzyme or "hormone."

To bring these facts into line with Mendelian principles it becomes necessary to postulate (1) two kinds of eggs, just as there are two kinds of spermatozoa, (2) selective fertilization, and (3) dominance of femaleness, and the observed facts can be explained. If the accessory chromosome is a sex-determinant, then when an egg is fertilized by a sperm lacking this element, the egg itself must carry the factor that determines that the sex of the resulting organism of 35 chromosomes shall be a male. In the event of the other possible combination the egg selected must have been one carrying the female determinant and, since the accessory chromosome is a male-determinant and the union of the two produces a sex-hybrid, femaleness must dominate in order to yield a female organism of 36 chromosomes.

The most recent position is that of Dr. Correns, professor of botany in the University of Leipsig, to the effect that there is only one kind of egg (always female) and two kinds of spermatozoa. He has brought forth facts to amply support this view in flowering plants. He shows that the spermatozoa determine the sex and that the time of this determination is the instant of fertilization. Correns attempts to bring the second position above mentioned into harmony with his own, and the facts upon which Beard's position is based are given a reasonable interpretation. We shall consider these various positions from Correns's standpoint, and will note how he disposes of the obstacles above referred to.

There are now known about one hundred cases, mostly among the air-breathing arthropods, where there is a dimorphism of spermatozoa. But if fertilization determines the sex, what about such cases where eggs develop without fertilization, as in the drone honey-bee, ants and plant lice (aphids and phylloxerans)? These several examples until recently had been serious stumbling-blocks to the theory that sex is dependent on a dimorphism of spermatozoa. Nor is the matter yet as clear as we could wish it to be. All the fertilized eggs of the honey-bee develop into females (workers or queens, depending upon the kind and amount of food they receive), the unfertilized eggs develop into males or drones. Meves has recently found that while the drone honey-bee produces two kinds of spermatozoa, one set, the male-producing, degenerates and becomes non-functional. Hence all fertilized eggs must develop into females. The facts become intelligible if we assume that all the eggs possess a predominating male tendency. There appears to be justification for this assumption since two polar bodies are formed and a reduction division takes place which may be thought of as partially eliminating the female tendency. Due to the preponderance of female elements, fertilized eggs become females. Unfertilized eggs become males, since the male tendency is undominated.

Aphids produce brood after brood of parthenogenetic females while food and climatic conditions remain favorable. When environmental conditions become adverse both males and females appear between whom eggs are fertilized, which as "winter eggs" resist the elements until the following summer, when they develop into parthenogenetic females. These facts may be thus explained: the original ancestor (stem-mother) of a parthenogenetic series arises from a fertilized egg; the eggs of the parthenogenetic females are all hybrids as to sex. No reduction is thought to take place when the single polar-body is formed. When conditions are favorable, metabolic activities give the ascendency to the female elements; when these become adverse, the male element gains the ascendency in some of the eggs. When males and females appear the sex determinants are segregated in the ova and spermatozoa in equal proportions in each. During maturation in the male aphid, however, Dr. N. M. Stevens, of Bryn Mawr College, and also Dr. W. B. von Baehr, of Germany, have discovered that half the sperm degenerate (these lack the accessory chromosome) and that these are male-producing kind. Hence, since only female-producing sperm remain, all fertilized eggs (sex-hybrids) must develop into females.

In the case of *Phylloxera,* where many generations of wingless parthenogenetic females appear while environmental conditions remain favorable, and when these become adverse, give way to winged males and females, Dr. T. H. Morgan has discovered a similar degeneration of the male-producing spermatozoa and the loss of a chromosome in the parthenogenetic males. In these cases we must assume that the eggs are intrinsically different (male and female), as they really appear externally, or else, as Correns proposes, that the eggs are potentially male and that in the fertilized egg where both sex tendencies are present femaleness dominates when environmental conditions are favorable to constructive metabolism. But some mechanism or condition must remain whereby an apparently homozygous male may produce spermatozoa bearing a female tendency. It is by no means proved that the whole quota of female tendencies (elements) is eliminated at maturation. The male and female (paternal and maternal) chromosomes are probably promiscuously arranged on the spindle. The persistence of chromosomes bearing female characters may supply the demands for the production of female-producing spermatozoa.

The sex of the offspring then appears to be the result of the interaction of two factors, both unknown quantities. By the union of an egg and a sperm an organism is produced which has a certain sex. If we let X represent the unknown sex tendency of the ova, and Y the unknown sex tendency of the spermatozoon, then we may state the process of sex production thus: $X + Y =$ sex of offspring. If we could discover the value of X or Y we could solve the equation and discover the secret of sex. Correns, as the result of experimentation with certain flowering plants since 1900, has found the value of X in these particular forms and has thus contributed invaluable facts for the reinterpretation of former observations and for the formulation of a wider generalization regarding sex phenomena.

Many facts are known which leave little doubt that in most animals sex is absolutely fixed in the fertilized ovum. A real exception is the case of the frog, where the embryo or even the larval tadpole is hermaphroditic, *i. e.,* it contains both ovaries and testes. In a later stage of development one or the other of these pairs of organs degenerates when the frog becomes a definitive male or a definitive female.

In the human species twins are frequently of the same sex, either male or female. Such twins are known as "identical twins" when enveloped in a common chorion or fœtal membrane. They are the result of an independent development of accidentally separated cells at the two-cell stage of development. Double monsters likewise are always of the same sex. "Ordinary twins" are as frequently of opposite sex as of the same sex. In this case each fœtus is enveloped in its own chorionic membrane. Such twins are the result of the synchronous development of two ova simultaneously successfully fertilized. These facts show that sex is already determined in the fertilized egg and before the first segmentation. Similar evidence is contributed by Jehring, who studied poly-embryony in a species of armadillo (*Tatusa hybrida*) found in Paraguay. Here as many as eight offspring appear at a single birth. Jehring reports that all eight fetuses are enclosed in a common fetal envelope. Hence the eight offspring must result from the development of the products of division as the eight-cell stage of segmentation. Since the offspring are all of the same sex, sex must have been already determined in the fertilized egg prior to the first cleavage. Again, Professor Silvestri, of Naples, has quite recently contributed new facts which lead to the same positive conclusion. He has discovered that *Litomastix,* a kind of bee (Chalcidæ), lays its eggs in the egg of a moth, *Plusia.* As the latter develops into a larval caterpillar, the egg of *Litomastix* segments into a chain of many eggs, each of which gives rise to an embryo bee. The caterpillar may contain a hundred such embryos and they are all of the same sex—female if the egg was fertilized; male if unfertilized. Sex must have been already fixed in the fertilized egg. But this is an entirely different matter from the position that Correns takes that sex is fixed at the time of fertilization and determined by the spermatozoa.

Correns made his experiments with two species of Cucurbitaceæ, the family to which our pumpkin and squash belong, growing wild in central Europe. These two species are *Bryonia alba* and *Bryonia dioica.* The former is the plant which supplies the root employed in pharmacology for the treatment of dropsy. The especial value of these species for experiments relative to the problem of sex, lies in the fact that the former is hermaphroditic or monœcious, *i. e.,* mature male and female flowers appear on the same plant; and the latter is diecious, *i. e.,* male and female flowers appear on different plants. These two species can be crossed in either direction. Correns made three sets of experiments, the results of which have led him to a unique and simple explanation of the cause of sex, in the light of which former theories must undoubtedly be more or less extensively modified. Correns first crossed *Bryonia dioica* with *Bryonia alba,* using the eggs of the former and the pollen grains of the latter. Sterile hybrid-offspring appeared from the cross and they were all *females.* Correns explains that since germ-cells of the hermaphrodite forms carry only hermaphrodite determinants, the male gametes (pollen grains) can have had no influence on the sex of the offspring of this cross. In other words, hermaphroditism is recessive to dieciousness. And since the offspring were all female, all the eggs of *Bryonia dioica* must have had female tendencies.

Correns next pollinated the pistils of *Bryonia dioica* with the pollen of the same species. Forty-one pure *dioica* offspring were obtained from this cross, twenty-one of which were female and twenty male, or in round numbers each sex appeared in 50 per cent. of the individuals. Since the eggs were all female, as shown by the first experiment, this result must mean that the pollen grains determine the sex and that they must be of two kinds, male and female in tendency, and approximately equal in number. It must also mean that the male tendency dominated over the female, else no males could have appeared.

In a third set of experiments the pistils of *Bryonia alba* were pollinated by *Bryonia dioica.* The offspring in this case were sterile hybrids, and of the seventy-six which came to maturity thirty-eight were male and thirty-eight female. This again shows that hermaphroditism is recessive to dieciousness since no hermaphrodites appeared. It shows also again that there must be two kinds of male gametes with male and female tendencies, respectively, of equal number, and that they determine the sex. It shows, moreover, that sex is determined at the time of fertilization, for before that instant all the female gametes (ovules) had the tendency to develop into hermaphrodite forms. It appears also in the light of this experiment that hermaphroditism and dieciousness must be regarded as unit characters, since they behave in crossing according to Mendelian laws. Hermaphroditism probably has its chromosome determinant as also dieciousness, hence the cytological study of the germ cells of hermaphrodite forms will hardly supply the clue to the cause of sex as it was until recently believed to do.

In those insects where there is a dimorphism of spermatozoa, consisting in the presence of an accessory chromosome in one half of the gametes, no obvious difference appears among the eggs. There are no real grounds for a division of the ova into those with male character and those with female character. In the light of Correns's recent observations, the eggs had better all be regarded as possessing the same sex tendency, and this probably female in nature. The spermatozoon with the accessory chromosome need then only be thought of as possessing the female tendency, and the one that lacks it, as possessing the male tendency, and the facts are brought into line with the results of Correns and admit of the same interpretation. In the case where large and small eggs are produced, as by *Dinophilus apatris*, it is conceivable that there is selective fertilization, *i. e.*, while both types of egg may be female in tendency, only the larger admit of fertilization by a female-producing spermatozoon.

The present status of the case concerning the determination of sex, as well supported for a large class of plants and animals, appears to be that sex is determined by the spermatozoa (or pollen grains)—which are male and female in the proportion of 1 : 1—and at the instant of fertilization. But surely it would be the utmost folly to hold on the basis of so comparatively few facts, that this explanation applies universally. Nature arrives at similar ends by devious and divers ways and it is not inconceivable that sex has been attained by several paths, and is now determined in different modes and at different times in the different groups of animals and plants.

JOSIAH WILLARD GIBBS AND HIS RELATION TO MODERN SCIENCE. II

By FIELDING H. GARRISON, M.D.,
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The Thermodynamic Potentials.[56]—In 1869 the physicist F. Massieu communicated to the French Academy of Sciences the discovery of two algebraic functions from which all the thermodynamic properties of a fluid may be derived.[57] These "fonctions characteristiques" of Massieu contain in latent form two of the four relations which Gibbs derived independently from his general thermodynamic equation and which have since been variously interpreted as the fundamental functions or thermodynamic potentials of heterogeneous chemical systems. Mathematically they are simplifications which dispense with the necessity of endless transformations of equations and formulæ, evolving, as Bryan says, "order out of chaos."[58] As the foundations of thermodynamics are its two laws, so the potentials may be regarded as the coping stones of the edifice, and all recent progress in the science, as in the physics of gas mixtures, osmosis, elastic solids or electrolysis has been made with their aid. The four potentials are now interpreted as the "free energy" (ψ) and the "modified available energy" or total thermodynamic potential (ζ) for constant temperature, and the intrinsic energy (ϵ) and heat function (χ) for constant entropy.[59] Of these the first two are the most important, being the analogues of the Newtonian or gravitational potentials (potential energies) of mechanical systems, generalized, as Larmor says, "so as to include the temperature" and connoting thermal effects,[60] just as the Maxwellian potentials connote effects of electromotive force. They

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[56] *Tr. Connect. Acad.*, III., 144–52.

[57] "J'appelle cette fonction *fonction caractéristique* du corps: en effet, lorsqu'elle est connue, on peut en tirer toutes les propriétés du corps que l'on considère dans la thermodynamique . . . Je rapellerai d'ailleurs qu'une fois la fonction caractéristique d'un corps déterminée, la théorie thermodynamique de ce corps est faite." F. Massieu, *Compt. rend. Acad. d. sc.*, Paris, 1869, LXIX., 859, 1058.

[58] Bryan, "Thermodynamics," Leipzig, 1907, 109.

[59] If ϵ, t, η, p and v represent the energy, temperature, entropy, pressure and volume of a chemical or thermodynamic system, its thermodynamic potentials will be the *intrinsic energy* ϵ obtained by integrating Gibbs's fundamental equation, the *free energy* $\psi = \epsilon - t\eta$, the *total thermodynamic potential* or "modified" available energy $\zeta = \epsilon - t\eta + pv$ and the *heat function* $\chi = \epsilon + pv$.

[60] Larmor, "Encycl. Britan.," 10th ed., XXVIII., 167.

represent that part of the energy of a system which is due to changes in its mass or structure rather than to thermal or molecular changes, and so can take part freely in physico-chemical transformations. For this reason the potential ψ, which is the difference between the total energy of a system and its bound (molecular) energy, was called the "free energy" of the system by Helmholtz, who rediscovered the principle independently, not knowing that Gibbs had forestalled his labors by at least six years. In lecturing on the subject during the later period of his life, Helmholtz, with his usual breadth of spirit, was inclined to assign complete priority to his predecessor,[61] while both Gibbs and Helmholtz have acknowledged their indebtedness to Massieu.[62]

Criteria of Equilibrium and Stability.—Gibbs's conditions for the complete equilibrium of an isolated homogeneous chemical substance are that its pressure, temperature and the chemical potentials of its components should be constant throughout the mass, since changes of pressure and temperature disturb mechanical and thermal equilibrium, while difference of potentials destroys stability and precipitates chemical change. For an isolated heterogeneous system, as an enclosed liquid and a gas in contact, the following maxima and minima are criteria of complete equilibrium: The system must have and maintain the greatest entropy consistent with constant energy; or for adiabatic systems (at constant entropy), the intrinsic energy (ϵ) or heat function (χ) should have minimum values for constant volume or pressure, respectively, but for isothermal systems (at constant temperature) the free energy potential (ψ) or the thermodynamic potential (ζ) should have minimum values for constant volume or pressure. Any deviation from these maxima or minima will again disturb equilibrium and produce changes of physical or chemical state. The essential feature of spontaneous chemical change is, then, either constant increase of entropy in self-contained or adiabatic systems or a corresponding decrease of free (mechanically available) energy in systems at uniform

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[61] "Deshalb hat Gibbs, der auch diese Form der Darstellung zuerst fand, die Function A das isotherme Potential genannt." Helmholtz, "Vorles. über theoret. Physik," Leipzig, 1903, VI., 269. See, also, the lecture in his biography by L. Koenigsberger, Braunschweig, 1903, II., 369: "In diesem Sinne hat Herr Gibbs die Grösse F. das isotherme Potential des Körpersystems genannt, ich selbst habe dafür den Namen der freien Energie vorgeschlagen, weil dieselbe Arbeitsäquivalente darstellt, deren Ueberführung in andere Formen der Energie nicht denselben Einschränkungen unterliegt wie die der Wärme." For Lord Kelvin's relation to the discovery of the free energy potential see *Proc. Roy. Soc. Lond.*, 1908, LXXXI., No. A 543, pp. xlvi–xlvii.

[62] "M. Massieu appears to have been the first to solve the problem of representing all the properties of a body of invariable composition which are concerned in reversible processes by means of a single function." Gibbs, *Am. J. Sc.*, 1878, 3. s., XVI., foot-note to p. 445.

temperature, or in Lord Kelvin's phrase, a general dissipation of energy in all irreversible phenomena. For each potential, with appropriate choice of coordinates, a solid model or relief map can be constructed, upon which the different minima of the potentials appear as depressions in the landscape. When the lowest depression or minimum has been reached, complete and permanent equilibrium is attained, and we have what Gibbs calls a "phase of dissipated energy," at which, as in a bar of metal or a block of granite, no further spontaneous changes of physical state are possible so long as the system remains isolated from external forces. In connection with his discussion of equilibrium we may note Gibbs's forethought in extending his equations to *n* dimensions, since for more than three components a three-dimensional model no longer suffices; his early introduction of the time element into the discussion of chemical reactions[63] and his pages on "passive resistance to change,"[64] which should be read by every chemist, since they are of the essence of his subject, especially in regard to carbon compounds or colloidal substances. In applying dynamic principles to chemical phenomena Gibbs, and after him Helmholtz, thought decrease of free energy at uniform temperature to be the most important condition for equilibrium, since it measures the actual work done and is thus the "force function" of mechanics with reversed sign.[65] The electromotive force of a reversible galvanic cell turns out to be identical with the free energy of chemical decomposition in the cell,[66] and in the field of biology free energy is of equal importance, for relative uniformity of temperature is as common in living processes as in the laboratory. Well did Boltzmann say that "the struggle for existence of living matter is a war for free energy," for when the free energy of a living body becomes a minimum its death is at hand.

The Phase Rule.[67]—Any aspect of a chemical substance which is homogeneous in regard to physical state and percentage composition has been called by Gibbs a *phase* of the substance, the components of a phase being its constituents of independently variable concentration. The phase rule asserts that a homogeneous substance having *n* components is capable of only $n + 1$ independent phases, while a heterogeneous system of *r* coexistent phases, each of which has *n* independ-

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[63] Gibbs, *loc. cit.*, 113.

[64] *Ibid.*, 111–3.

[65] See Gibbs, *Am. J. Sc.*, 1878, 3. s., XVI., 442. "The transition from the systems considered in ordinary mechanics to thermodynamic systems is most naturally made by this formula . . . the mechanical properties of a thermodynamic system maintained at constant temperature being such as might be imagined to belong to a purely mechanical system, and admitting of representation by a force function."

[66] Gibbs, *Tr. Connect. Acad.*, III., 520.

[67] *Ibid.*, 152–6.

ently variable components, is capable of $n + 2 - r$ degrees of freedom or variations in phase, of which not more than $n + 2$ can coexist at the same pressure and temperature. Such systems, in Trevor's nomenclature, are spoken of as invariant, monovariant, divariant, etc., according to the number of possible variations of state. Thus water (H_2O) has three independent phases, ice, liquid and steam, and is invariant, the three phases being in equilibrium at only one pressure and temperature, called the triple point, where the steam-line, ice-line and hoar-frost line meet. But when calcium carbonate ($CaCO_3$), calcium oxide (CaO) and carbon dioxide (CO_2) are in equilibrium, we have three coexistent phases formed of two components (CaO, CO_2) and the system is monovariant. By this rule the chemist is able to predict the number of modifications of which a chemical substance is capable from observation of its physical properties alone, or the number of substances in a mixture from notation of the number of phases possible, or the strength of a saturated solution from its temperature and pressure. Many different proofs of the phase rule have been given by mathematicians and physicists from varied and independent points of view,[68] and there is every indication that it is a complete and accurate statement of a general chemical law. Its practical significance remained for a long time undiscovered until the Dutch chemist Van der Waals took it up, and when, in 1884–6, his colleague, Bakhuis Roozeboom, found himself unable to explain certain puzzling phenomena connected with the equilibrium of gaseous hydrates and of double ammonium salts, van der Waals was able to direct his attention to Gibbs's theorem and showed him, by working out a special case, how thermodynamic methods might be applied to practical chemistry.[69] From that time on Roozeboom became the devoted champion of the phase rule, which he compares to the ground plan of a gigantic building in which all the collected phenomena of chemical equilibrium can be stored in a convenient and comprehensive manner. "This structure," he adds with pride, "has since been completed, almost exclusively by the work of the laboratories of Leyden and Amsterdam."[70] In fact, the investigations of Roozeboom and van't Hoff upon double salts, solid solutions and metals are among the most brilliant results of modern chemistry. It is in connection with the graphic study of chemico-physical changes by the phase rule that Gibbs's diagrams and surfaces

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[68] Nernst, "Lehrb. d. theoret. Chemie," 2. Aufl., 564. Wind, *Ztschr. f. phys. Chem.*, 1899, XXXI., 390. Kuenen, *Proc. Roy. Soc. Edinb.*, 1899–1901, XXIII., 317; *J. Phys. Chem.*, 1899, III., 69. Le Chatellier, *Rev. gén. d. sc.*, 1899, 759. Saurel, *J. Phys. Chem.*, 1901, V., 31, 401. Trevor, *ibid.*, 1902, VI., 185. Wegscheider, *Ztschr. f. phys. Chem.*, 1903, XLIII., 93, 113. Raveau, *Compt. rend. Acad. d. sc.*, 1904, CXXXVIII., 621. Mueller, *ibid.*, 1908, CXLVI., 866.

[69] Roozeboom, "Die heterogenen Gleichgewichte," 1901, I., 7.

[70] *Ztschr. f. Elektrochem.*, 1907, 94.

have proved of greatest value. The triangular diagram which he originally proposed for this purpose[71] has been so improved by Roozeboom[72] that the study of the chemical changes of a heterogeneous system and the prediction of its possible degrees of freedom become for the skilled worker a simple and easy matter.

Scientific Applications of the Phase Rule.—The doctrine of phases gives the chemist a new way of looking at things, serving at once as a basis of classification and a guide in qualitative research, and in contradistinction to the older gravimetric chemistry which dealt with some one continuous state of an isolated substance, it inaugurates the chemistry of substances in contiguity. Here the phase rule bears the same relation to physical chemistry that the periodic law of Lothar Meyer and Mendelejeff does to inorganic chemistry. Although only qualitative in its application it gives the chemist a new *fundamentum divisionis* by components and phases, necessitating a revision of substances, of which many formerly recognized as compounds are now no longer listed as such, while many new compounds have been introduced.[73] In analytical chemistry the phase rule has found its widest application in classifying our knowledge of the dissociation of solid substances such as alloys, solid solutions, cryohydrates, tartrates, basic double and racemic salts, or in the solution of such special problems as the changing solubilities of metallic hydrates or the distributions of a dissolved substance between two solvents which do not mix. For example, Roozeboom discovered by the phase rule that four different hydrates can be formed with ferric chloride, of which only two were known before his investigation,[74] while van der Heide's studies of the double sulphate of potassium and magnesium (Schönite) revealed the possibility of at least fifteen heterogeneous modifications of phase.[75] No less than thirty different ferric sulphates are now on record,[76] and Bancroft has said that a general system of qualitative research is not possible until we have studied the properties of such multi-component systems. Tammann's researches on the equilibria subsisting between solids and their melted states indicate that nearly all such substances have more than one solid modification of phase,[77] while van't Hoff

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[71] Gibbs, *Tr. Connect. Acad.*, III., 176.

[72] Roozeboom, *Ztschr. f. phys. Chem.*, 1894, XV., 143; *Arch. néerl.*, 1895–6, XXIX., 71. Bancroft, *J. Phys. Chem.*, 1896–7, I., 403. In 1891, Sir G. Stokes suggested the graphic representation of physical states of ternary alloys by means of an equilateral triangle which he derived independently from Maxwell's color diagram. (*Proc. Roy. Soc. Lond.*, 1891, XLIX., 174.)

[73] See Professor Bancroft's *Journal of Physical Chemistry* (*passim*), from which most of the results in this section are taken.

[74] Roozeboom, *Ztschr. f. phys. Chem.*, 1892, X., 477.

[75] Van der Heide, *ibid.*, 1893, XII., 416.

[76] Cameron, *J. Phys. Chem.*, 1907, XI., 641.

[77] Tammann, "Kristallisieren und Schmelzen," Leipzig, 1903.

has completely revolutionized our knowledge of the double salts and of geological formations. One of the most beautiful applications of the phase rule is found in van't Hoff's investigations of the oceanic salt deposits at Stassfurt,[78] in which from a laboratory study of the equilibrium obtaining between the sulphates and chlorides of sodium, calcium, magnesium and potassium the great chemist was able to reconstruct the past history of the formation of the earth's crust from the primeval ocean, giving even the limits of time, the pressure and the probable temperature at which the water evaporated. The importance of such methods in mineralogy and geology is self-evident and clearly as extensive as the subjects themselves. In metallurgy the work of Roozeboom, Le Chatellier, Sorby, Stead and others on steels, bronzes, tins, alloys and ingots of metal generally have, with the aid of the microscope, given us most valuable knowledge of the continuous chemical changes and "diseases of metals" going on in these substances, which, without the guidance of the phase rule, were formerly investigated in an aimless and haphazard way, at enormous expense and waste of time. Investigations of the very complicated equilibria in such "solid solutions"[79] as carbon-steels, nickel-steels, cobalt-steels, etc., have explained the causes of brittleness and crystalline structure in steel-rails through extended use, and how such rails can be renewed by prolonged heating at high temperatures. "The variations of the engineering properties, such as tensile strength, torsional resistance, ductility, etc., with varying concentration and varying heat treatment, is a subject which can only be worked out satisfactorily with the phase rule as a guide," says Bancroft, and he adds, "we do not yet know one half the properties of our structural metals." The establishment of the true constitution of Portland cement is another telling application of the phase rule and it is thought that it will give us "clearer ideas as to the strength of cements and the elasticity of clays." Lord Kelvin expressed the hope that some day the architect might be in effect a sanitary engineer,[80] and Bancroft predicts that "the time will come in our engineering schools when the subject known as 'materials of engineering' will have to be taught by the chemist rather than by the engineer."[81]

In agricultural chemistry the phase rule serves as a guide in the

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[78] Van't Hoff, "Lectures on Physical Chemistry," Chicago, 1907.

[79] Solid solutions are solids dissolved in solids, and were first described by van't Hoff (*Ztschr. f. phys. Chem.*, 1890, V., 322), who found that when certain solutions are frozen, the separated solid is not the pure solvent, but a mixture of the selvent and the solute, *i. e.*, a solid solution, of which we have examples in the alums, glasses, colored and hyaline minerals, alloys and the "ice flowers" of the Antarctic regions.

[80] Kelvin, "Popular Lectures," 1894, II., 210.

[81] Bancroft, *J. Phys. Chem.*, 1905, IX., 209.

investigation of soils. "The soil is the stomach of the plant," being in effect a complex system in three phases, of which the liquid phase furnishes the nutrient solution to the plant. The bacteria, molds and enzymes in the soil make its relation to the plant a complicated and difficult problem,[82] but the application of physical chemistry to its solution of Cameron, Bell, Briggs and other chemists in the United States Department of Agriculture is clearly in the right direction. Recently Bancroft has shown how the phase rule may be applied to photochemistry when the radiant energy of absorbable light such as ultraviolet is converted into chemical energy. The light acts as another variable requiring $n + 3$ phases in an invariant system while in general we may have as many additional degrees of freedom as there are kinds of light.[83] The application of the phase rule to organic chemistry is difficult owing to "passive resistance to change." Most of the reactions in organic chemistry are reversible, *i. e.*, proceed to equilibrium, and if sufficient time be allowed will reverse backwards like a Carnot cycle, to some approximation of their initial state. Many reactions with organic substances, however, seem to stop short of equilibrium, and the chemist, in working with colloids, ferments, gums, etc., is balked by certain passive forces, which do not, like friction or viscosity, merely retard chemical change, but actually prevent it. Even such explanations as the hypothesis of reversibility in infinite time or Duhem's theory of false equilibria and pseudoreversible reactions, do not entirely account for these mysterious phenomena, and it is probably through new methods of laboratory procedure that organic chemistry will ultimately pass into the hands of the physical chemists.

In physiological chemistry the doctrine of phases opens out a new perspective, a new qualitative way of envisaging problems which, approached quantitatively, are a severe task even for an Emil Fischer. Recently the Dutch physiologist Zwaardemaker has proposed the application of the phase rule and the second law to general physiology.[84] "The task of an energetic histology," he says, "would be to give the number of phases and their relations, while an energetic physiology would determine the equilibria and reversible processes by direct experimentation."[85] Zwaardemaker proposes to regard the human body at rest as a complicated system of coexistent phases in equilibrium, the metabolic, reproductive and other processes of which are irreversible. The animal cell he holds to be a system of heterogeneous phases, the equilibrium of which can be disturbed by experimental removal of the nucleus. The red blood corpuscles are probably divariant, four component systems of four phases, while the endothelial cells of the ven-

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[82] Cameron, *ibid.*, 1904, VIII., 642.

[83] Bancroft, *ibid.*, 1906, X., 721.

[84] Zwaardemaker, "Ergebnisse d. Physiol.," Wiesbaden, 1906, V., 108.

[85] *Loc. cit.*, 154.

tricle of the heart are examples of a monovariant system. The "pressure phosphenes" of the retina, luminous sensations produced by pressure on the eyeball, and consequently "eye strain," may be due, Zwaardemaker thinks, to displacements of equilibrium through disturbance of the thermodynamic potential. These speculations are, of course, tentative, but there are indications that physiological problems may be attacked in a way that has some show of success in that it is qualitative.

The Law of Critical State.—When we have two contiguous phases of a substance, as a liquefying gas or a vaporizing liquid, there is a point where the two become continuous. This is called the critical state at which the distinction between coexistent phases vanishes. Gibbs's law asserts that a critical phase of independently variable components is capable of $n - 1$ independent variations. This theorem is the basis of the brilliant work of van der Waals, Duhem, van Laar and Kamerlingh Onnes upon continuous gaseous and liquid states.

Osmosis and the Theory of Solutions.—Gibbs's work is remarkable throughout for his avowed or explicit intention to have "nothing to do with any theory of molecular constitution" as leading to strained and unnatural hypotheses, and the wisdom of his decision is seen in his earlier treatment of the equilibrium of osmotic forces. He bases his theory of osmosis upon the idea of a semi-permeable diaphragm or membrane, which he introduced into physics as a purely theoretical concept, leaving the actual facts about it, he says, "to be determined by experiment." This ideal membrane, which he supposes permeable to one component and impermeable to others, is the key to the theory of solutions, for, to the mathematician, it admits of the condition of reversibility which he finds in algebraic or chemical equations; to the physicist, a solvent in the act of breaking up or wedging its way through a dissolving substance is the dynamic analogue of a liquid forcing its way into a denser liquid through the membrane, while to the chemist, the assumption that the membrane is selective for certain substances only implies some special chemical affinity between these substances and the membrane itself. If two fluids of different composition or concentration, say water and alcohol, are separated by a semi-permeable membrane, the osmotic flow of the water into the alcohol is due to definite forces. These, in Gibbs's argument, are, not a difference in pressure, but a difference in temperature which disturbs thermal equilibrium or a difference in the chemical potentials *of components which can pass the diaphragm*, the condition for equilibrium being equalized temperature and equality of chemical potentials. "Even when the diaphragm is permeable to all the components without restriction," he says, "equality of pressure in the two fluids is not always necessary for equilibrium."[86] While Gibbs did not attempt a definite theory of solu-

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[86] See his abstract in *Am. J. Sc.*, 1878, 3. s., XVI.

tions, it is clear that he regarded osmosis as a chemical or thermodynamic phenomenon. Let us see how his mathematical theory agrees with the facts of recent investigations. The mathematician Cayley thought double-entry bookkeeping an example of a perfect science, because its theory and practise are in complete agreement, so that the detection of sources of error becomes simply a matter of expert skill. For similar reasons one of the principal aims of modern physical chemistry has been to arrive at an adequate theory of solutions as a guide in chemical and biological research. Such a theory has been proposed by van't Hoff, who, starting from Pfeffer's measurements of osmotic pressure, bases his argument upon the widely known equation which asserts that osmotic pressure in very dilute solutions obeys the laws of Boyle, Gay Lussac and Avogadro with the same physical constants that obtain in mixtures of dilute or ideal gases.[87] Pushing this analogy with gases farther, van't Hoff implicitly denied that there is any specific attraction between the solvent and solute (dissolved substance) or that the alleged semi-permeable membrane plays any active part in osmosis, holding that "osmotic pressure," like the pressure exerted by rarefied gases, is a real initial pressure caused by a bombardment of the membrane by the dissolved molecules. Now van't Hoff's equation, which Gibbs anticipated for dilute solutions of gases in liquids, and of which van't Hoff, Lord Rayleigh[88] and Gibbs[89] have each given rigorous thermodynamic proofs, was found to be true to the laboratory measurements for extremely diluted solutions of sugar and other substances, but (as Lord Kelvin said ten years ago) "wildly far from the truth" for solutions of acids, bases and salts.[90] Arrhenius, in his theory of electrolytic dissociation,[91] has explained these discrepancies as "harmonies not understood," due to free dissociation of ions in water and to increase of molecular conductivity with dilution; but Lord Kelvin's objection has still some force to this day. Two schools of chemists have thus arisen, one of which seeks to approximate the laboratory facts about solutions to van't Hoff's dynamic analogy with the gas laws, the other holding that osmosis is bound up with an ascertained selective action of the semi-permeable membrane, osmosis and solution being both due to "chemical affinity." Most prominent among those who have opposed the view that real solutions behave like ideal gases, are Louis Kahlenberg and J. J. van Laar. The special service of Kahlenberg has been to discredit the molecular or dynamic analogy between gases and liquids and to emphasize the point made by Fitzgerald in

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[87] Van't Hoff, *Ztschr. f. phys. Chem.*, 1887, I., 481.

[88] *Nature*, London, 1896–7, LV., 253.

[89] *Ibid.*, 461.

[90] *Ibid.*, 273.

[91] *Ztschr. f. phys. Chem.*, 1887, I., 631.

1896, that "chemical forces are of a far more complex nature than electrolysis."[92] Accepting the contention of the van't Hoff school that the gas equation and the Arrhenius theory are only true for infinite dilution, Kahlenberg has turned a clever flank movement upon them by insisting that if liquids act like gases we should expect a solution of increased concentration to behave at least qualitatively as gases do on increase of pressure. As a matter of fact, although practically all gases act alike, different solutions do not, as a rule, and solutions of solids in liquids, or liquids in liquids, do not behave like solutions of gases in liquids or gases in gases. Furthermore, the Arrhenius theory does not agree with many facts about aqueous solutions, while it falls completely to the ground for solvents other than water. This does not mean that Kahlenberg opposes electrolysis or electrolytic dissociation as such, or that he would have us abandon hypotheses of such value before we have found better ones, but he insists that "the question why certain solutions, molten salts, etc., conduct electricity and others do not will probably not be answered until we can tell why a stick of silver conducts electricity and a stick of sulphur does not."[93] Morse and others have shown that the van't Hoff equation and the Arrhenius theory are true for very small dilutions, that is for solutions so mathematically ideal that they are practically independent of the nature of the solvent and the solute, but the experiences of Kahlenberg have shown that they are not always true for actual solutions of reasonable concentration. Moreover, the fact that the solute in tenth-normal solutions acts like a gas by no means explains all the phenomena of solution. Kahlenberg's experiments with semi-permeable membranes[94] show that such membranes, while passive for gases, are active or selective for different liquids, so that the initial movement and actual direction of the osmotic current are determined by the specific nature of the membrane itself and of the liquids bathing it. Semi-permeable membranes, therefore, exist as such, and although none are strictly ideal in Gibbs's sense, their true "semi-permeable" or selective character is indicated by Kahlenberg's discovery that in some cases true measurements of osmotic pressure can not be obtained unless the solution is stirred to increase chemical action. The semi-permeable membrane shows that osmotic

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[92] "That other than purely electrical forces are operative in solution is indicated by Helmholtz's investigations of electrical diffusion through fine tubes." Fitzgerald, Helmholtz lecture, *Nature*, 1895–6, LIII., 297.

[93] Kahlenberg, *Phil. Mag.*, 1905, 6. s., IX., 229.

[94] Kahlenberg, *J. Phys. Chem.*, 1896, X., 141–209. Recently Tammann has advanced the view that in ideally diluted solutions the solute acts like a gas, while in concentrated solutions there is a chemical interaction between the solvent and the solute, and such solutions behave more like the solvent under higher pressure. (Tammann, "Ueber die Beziehungen zwischen den inneren Kräften und Eigenschaften der Lösungen," Leipzig, 1903.)

pressure is not an initial force, but a secondary hydrostatic pressure due "to the same affinity which produces adhesion, imbibition, absorption, adsorption, solution and chemical action." But all these forces are reducible in the simple reasoning of thermodynamics to the difference in temperature (Carnot's principle) and differences of chemical potentials which promote chemical change. As to molecular bombardment, "osmotic pressure," said Fitzgerald, in 1896, "is more nearly related to Laplace's internal pressure in a liquid which depends upon intramolecular forces, than to a gaseous pressure which is practically independent of the forces acting between the molecules."[95] Van Laar pictures a sugar solution of reasonable concentration as made up of crooked movements of molecules, slowly crowding upon one another, with no intervening spaces, totally different from the rapid billiard ball movements with wide repulsions that are supposed to obtain in diluted gases. Osmosis, in van Laar's theory depends not upon the molecules of the dissolved substance, but upon the solvent itself, which, having the higher chemical potential, moves toward the solute. To explain the phenomena of osmosis by appealing to an initial osmotic pressure, says van Laar,[96] is like saying that an angry man's loud talk and unseemly gestures are due to his red face.[97] Anger is the real cause of both. So the movement in osmosis, which produces a difference in hydrostatic pressure, depends initially upon differences of chemical and thermodynamic potentials. Beyond this we know absolutely nothing of the interaction between the solvent and the solute. Again Bancroft has shown that the pressure for finite solutions in osmosis varies with the heat of dilution, which again varies with the specific nature of the solvent and the solute.[98] All this brings us back to Gibbs's fundamental position that osmotic pressure "is a function of the temperature and the n potentials."[99] From this point of view, Graham's original doctrine, that osmosis is the conversion of chemical affinity into mechanical power,[100] is at once true to the mathematical theory and the laboratory facts. If now we agree with Whetham that "osmotic phenomena are intrenched in the strongest part of the vast lines occupied by the science of thermodynamics," it is clearly due to the early pioneer work of Gibbs that this vantage ground was gained in the first instance, while the molecular theory of osmosis remains in the debatable land of controversy and a true theory of solutions is still far to seek.

(To be continued)

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[95] Fitzgerald, *Nature*, London, 1895–6, LIII., 297.

[96] Van Laar, "Sechs Vorträge über das thermodynamische Potential," Braunschweig, 1906, 3.

[97] *Ibid.*, 34.

[98] Bancroft, *J. Phys. Chem.*, 1906, X., 319–29.

[99] Gibbs, *loc. cit.*, 139.

[100] Graham, *Phil. Tr.*, 1854, 227.

SUGGESTIONS FROM TWO CASES OF CEREBRAL SURGERY WITHOUT ANESTHETICS

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FOR the first time, so far as I am aware, there have been placed on record two cases of cerebral surgery, accompanied by somewhat extensive explorations of the brain-substance, without the use of anesthetics. The suggestions afforded, and the problems further opened, by these cases are so interesting from the psychological point of view that it seems to be desirable at least to call to them the attention of this association. Only one of these cases has as yet been reported in print;[1] for some of the facts connected with the other case I am indebted to correspondence with the operating surgeon, Dr. Harvey Cushing, of Johns Hopkins University.

Briefly described, the case of which we have the fullest report was as follows. The patient, R. C., was 32 years of age, unmarried, a farmer and teacher, a man quite up to the average of his class in intelligence, and of excellent moral habits. Previous to the beginning of his present trouble he had been in excellent health. When nine years of age he received a slight blow on the head; later, he received a blow from a baseball bat which fractured his nose. No other causes of possible cerebral injury were discoverable. About the year 1895 he began "to suffer from curious nervous attacks, which came on without cause." These consisted of strange sensations in the head, and twitchings of the left calf. But there was no loss of consciousness and the seizures lasted only a few minutes. With these symptoms there subsequently became associated tingling sensations, which sometimes spread up the left leg even to the thorax and the left arm, and more extensive twitching of the muscles, spreading itself in the same direction. These seizures were followed by numbness in the parts involved; but until July, 1900, there were no fits with complete loss of consciousness; and at the time of the first operation loss of consciousness had occurred only six times, although during the ten years previous there had been several hundred seizures.

The patient had, however, been subject to headaches from childhood, and these became more and more severe after the nervous at-

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[1] "Removal of a Subcortical Cystic Tumor at a Second-stage Operation without Anesthesia" (reprinted from the *Journal of the American Medical Association,* March 14, 1908, Vol. I., pp. 847–856).

tacks already described. For three months early in the year 1903, the headaches were particularly intense, and this period of intense pain in the head ushered in a period of definite occular symptoms, consisting of momentary attacks of blindness, followed by diplopia for two or three days. The headaches suddenly disappeared, but there was permanent loss of visual acuity, weakness of the left leg, and general nervousness.

At the time the patient entered the hospital, careful examination of the nervous condition gave the following results: The optic nerves seemed atrophied and there was some constriction of the visual fields. There was distinct hemiplegic limp on the left side, a slight weakness in the dorsal flexion of the left ankle, and possibly also in the flexion of the knee and hip. The reflexes of the left leg were also somewhat exaggerated. On the contrary, sensation seemed to be normal over the arm and hand. The deep reflexes in the arms and right leg were normal. The sensibility of the right leg and foot were without discoverable abnormality.

The conclusion of the diagnosis made at this time affirms: "It was evident that the patient was suffering from an organic lesion situated in the upper part of the Rolandic region, involving the cortex itself or lying just below it."

Four different operations were performed for relief of this patient, between the dates of November 22, 1906 and March 21, 1907. These were all unsuccessful and did not even reveal the cause of the malady, and this unfavorable result was chiefly due to the fact that the patient bore anesthetics—both chloroform and ether—so badly and the cyanosis was so profound and threatening as to compel the surgeons to abandon their attempts at further exploration of the brain, lest it might lead to a fatal result. Moreover these operations served to show that the exposed surface of the brain was entirely normal in appearance; and when this part of the cortex was faradized, there was no abnormality of motor response. "Clean-cut movements were elicited in the toes, lower leg and thigh." In the same way movements were also obtained in the thoracic muscles, in the lateral abdominal muscles and in the muscles of the shoulder; and from still lower centers were obtained flexion of the elbow and flexion of the wrist. Posterior to the central fissures no motor responses could be elicited.

Following the third operation, or on and after December 23, 1906, the seizures increased in severity. Aggravated by the weakness following an attack of bronchial pneumonia in January, 1907, the nervous symptoms increased to one or more daily, consisting of severe epileptiform fits which involved the entire body, and always with loss of consciousness.

The constant and urgent request of the patient for relief, at all risks, from his distressing condition, induced the doctors to attempt the fourth operation; and when this was unsuccessful even to the extent of revealing the abnormal conditions, to the fifth operation, which was without anesthetics and which is the one chiefly interesting from the psychological point of view.

This fifth operation was performed March 26, 1907. The bone flap was for the fifth time reflected; the dura was incised some distance outside the largest previous incision; an incision was made into the gyrus centralis posterior, which appeared somewhat flattened and yellowish in color; and about one centimeter below the surface the top of a thin-walled cyst came into view. By enlarging the incision until it measured 5 centimeters this cyst was removed; but below it a still larger cyst was disclosed, which was "in turn shelled out of its bed by pushing the brain away from it, and was in this way removed unruptured." The entire procedure lasted about three hours.

But what about the mental condition of the patient during this long-continued and extensive exploration and cutting and pulling of the brain and its integuments? We are informed that he was "interested," asking questions and conversing with the doctors most of the time. Although perfectly conscious, he "experienced no sensory impressions whatever, even when the dura was incised." The only discomfort, not to say pain, given to him by these extensive explorations of his brain, was when the edge of the incision of the dura was caught in a clamp and the membrane dragged upon. The patient himself called the attention of the surgeons to an otherwise unnoticed phenomenon which consisted of a slight twitching of the muscles of the left side and shoulder.

In his report Dr. Cushing expresses his regret that this rare opportunity was not seized in order to test the effects of stimulating the posterior and post-central convolutions upon the experience of conscious sensation. In a subsequent case of cerebral surgery without anesthetics, however, these convolutions were stimulated and distinct impressions of sensations were obtained which were localized by the subject in the extremities and not at all in the cortex itself.[2] No such sensory impressions were obtained by stimulating the pre-central area, or "motor strip," although the customary motor results were obtained. Further details of the second case were not at my disposal at the time of writing this paper.

The following remarks upon these surgical results as viewed from the psychological point of standing are intended as suggestions rather than as definitely established conclusions.

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[2] Still more recently, as I have learned in conversation, in a third case of cerebral surgery without anesthetics, the same operator obtained similar results of conscious sensations by faradizing the same region of the cerebral surface.

And, first, it would seem that the cerebral hemispheres, including their integuments, are largely or completely devoid of the capacity of self-feeling. It has been known for some time that the substance of the brain is insensitive to pain; but it has hitherto been held that the dura is a highly sensitive tissue. This belief was strengthened by the knowledge that this membrane receives its innervation from the trigeminal nerve, and by the experience that in trephining the lower animals, when the dura is reached, struggling, and rise in blood-pressure are common. But here was a fully conscious subject, able intelligently to describe his sensations, who felt no pain while the membranes over that part of the brain which is allotted to sensory impressions were incised and manipulated. This experience, therefore, throws back upon us the problem: What is it that causes intracranial pain, especially in the form of those intense headaches which follow upon disturbances of the cerebral blood-supply, or in cases of cerebral lesion like that now under discussion? May we not find that the causes of the pains which we locate in the cerebral hemispheres invariably lie outside of those hemispheres? Certainly, it is not strange that the localization in such cases should be even more indefinite than in the case of an aching tooth or some form of abdominal distress. Indeed, cerebral pains and other forms of discomfort, with their accompanying mental disturbances, may be so severe as to result in insanity, and yet the location of the irritating causes, whether nearby or remote from the brain, remain undiscovered.

Second, there is both additional light and increased confusion contributed by these cases of cerebral surgery without anesthetics to the problem of the functions of the post-central and so-called sensory convolutions. In both these cases stimulation of the motor strip called out motor responses; stimulation of the post-central area failed to call out motor responses. More important still by far is the fact that, in the second case, stimulation of the post-central convolutions was followed by distinct sensory impressions—not mere signs of such impressions, but conscious sensations, testified to in language by their subject; and these sensory impressions were located in the extremities and not at all in the cortex itself. This is definite and fairly conclusive evidence to the functional value of the post-central convolutions. But now, on the other hand, we have the fact that, although the incision was made in the middle of the field supposed to be especially if not exclusively sensory, no subjective sensations whatever were called forth in this way; and the yet more startling fact—I quote the words of Dr. H. M. Thomas, clinical professor of neurology in Johns Hopkins University—that,

> With a tumor situated in large part in the post-central convolutions and involving a considerable portion of its superior part, there was practically no objective sensory loss. I think it may fairly be said that before the first

operation, even after numerous and thorough examinations, no definite objective sensory disturbance could be detected. The tests were particularly devised to estimate the power of localization and the power of recognition of objects felt.

All this accords with the evidence upon which our whole localization theory is based. This evidence tends to show: (1) that the different forms of mental functioning are not absolutely dependent upon definitely circumscribed and permanently fixed portions of the cerebral hemispheres; and (2) that by mental development a relative independence of the particular areas originally connected with the different forms of mental functioning may be attained. From the physiological point of view the cerebral substance appears as plastic and educable to a degree until recently unsuspected. And any dislocation or interruption of the proper connections becomes more dangerous than even a considerable loss of the brain-substance. From another point of view the same conclusion was reached in a paper entitled "A Suggestive Case of Nerve-Anastomosis," which I read before the Psychological Association at its meeting in 1904. I take this opportunity to call attention to the fact that Dr. Cushing by a purposeful division of the facial nerve and its anastomosis with the spino-facial, has more recently succeeded in restoring to the patient a considerable degree of normal emotional control of the expressive muscles of the face. I leave to expert physiologists to conjecture what new adjustments in their related forms of functioning this required from the cerebral hemispheres.

Third, these cases of cerebral surgery without anesthesia would seem further to confirm what has for some time been held to be true —namely, that slow abnormal developments, even when they finally involve much more serious destruction of the cerebral areas, and interruptions of the normal connections, are tolerated much more easily than sudden and rapid lesions or other abnormalities. Nor does it appear wholly out of place to say that while this education of the cerebral hemispheres to unwonted functions requires time, the emotions and will of the conscious agent are factors of the greatest importance in securing the results of this education.

Finally, there is one thought which I bring forward, not as a matter of argument, much less of proof; but, the rather, as a personal impression amounting almost to a conviction. In stating this impression I will take the liberty to employ the language of an "old-fashioned" but by no means altogether discredited psychology. Here is an intelligent human soul; he remains perfectly conscious, free from pain, and taking a lively interest in a surgical operation which explores, incises, pulls about, and otherwise manipulates, and finally drags two large abnormal growths out from, what is known to be the most important part, for the life of conscious sensation and voluntary motion, of his own brain. From the anatomical and physiological points of view, this picture is sufficiently startling. But when I take the more purely psychological point of view, I am impressed with the conviction that we are here dealing with the reality of a soul, as a spiritual agent, which while it is confessedly dependent for its development upon the development and normal functioning of the nervous centers, is, nevertheless, capable of attaining in the exercise of its higher and more complex forms of self-consciousness, a relative independence of those nervous centers. And if we ask ourselves whether this independence *may* perchance become absolute, after the destructive forces of nature have completely disintegrated the cerebral substance, we can not, indeed, answer "Yes," with the certainty of positive science. But upon my mind the impression made by such experiences as these is favorable to the affirmative answer. And so far as positive science can answer the inquiry at all, or even throw much light upon it, I prefer to follow along the lines of the seen and tangible and universally verifiable, rather than take the leap involved in a premature interpretation of doubtful phenomena by hypotheses touching the wholly unseen and intangible. Here, at any rate, is this conscious soul, manifesting itself as a partially "disembodied spirit." Its voice I can hear and interpret as one of my own kind. This manifestation appeals to me at present, and in accordance with scientific methods, much more strongly than any alleged communications from wholly disembodied spirits. Perhaps, however, at sometime in the future of the physical and psychological sciences, the two voices may speak with one accord.

HYSTERIA AS AN ASSET

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AT about the time that Commodore Vanderbilt was establishing in America the methods which made railway travel easy, a book was published in London which left untouched all problems of construction and management, but nevertheless played an important part in the economics of transportation. This book treated of railway injuries and was written by England's foremost surgeon, John Eric Erichsen. It brought together for the first time, in concrete form, the nervous disturbances from which the victims of railway wrecks suffer so severely; and by chronicling the large sums of money awarded in such cases as were litigated, it showed how important an asset "railway spine" might be. It soon became a best seller. It was indispensable to physician and attorney alike; and transportation companies had to have it to protect themselves against the menace of the new disease. It almost became a court manual at this epoch, when the quickening of railway movement was beginning to crowd court calendars with damage claims. For nearly twenty years it stood unchallenged and without a rival. Its influence was felt the world over, for it carried with it a money importance such as seldom follows the writings of medical men.

All this was half a century ago. Since then, new knowledge and new ways of getting it have shown that Erichsen taught mostly error; and his monograph, once so opportune and never to be stripped of the glory of the pioneer, is nothing now but a historical document. It was a costly book for railway companies. The cases it described were serious and "railway spine" brought large verdicts. It was not until 1882 that its teachings were seriously questioned. Then Page, surgeon for the London and Northwestern Railway, took a hand. In vigorous language, he presented new facts as seen by the railway surgeon. He brought forward the after histories of over two hundred cases of railway injuries and showed, contrary to Erichsen's teachings, that a large proportion of them recovered. He wrote with candor, but being a corporation servant, could not escape the charge of bias.

But Charcot was not biased, and when, in his studies of hysteria, he began to demonstrate the mental origin of many physical symptoms, the subject received its true illumination. Thoughtful physicians could no longer fail to realize that railway injuries are not essentially different from any others; that the mutilations are such as surgeons see resulting from a variety of causes, and that the nervous symptoms which so often follow accidents on railways are mental rather than physical and are the same as originate from any one of a great number of emotional experiences. And so "railway spine" passed away and in its place came physical injuries and several groups of psychic phenomena which a great German called the "traumatic neuroses"—"traumatic" because of the accident, "neuroses" because the nervous system, though out of order, has sustained no physical damage and is capable, sooner or later, of resuming its normal functions.

With the spread of industries and the ever increasing frequency of claims for damages for personal injuries, these cases have become everyday occurrences. Physicians the world over have had abundant opportunity to observe their mode of origin, their course, and (though this with greater difficulty) their final outcome. And there is almost universal agreement of opinion that fright at the time of the accident and anxiety after it are the true causes. The cuts and bruises which must be received if the injury is to be actionable (151 N. Y.) intensify the psychic factors. But they do not cause the nervous symptoms, though they may determine, to some extent, their trend.

That this agreement of opinion is not always manifest when these cases come to court may cause regret but not surprise. Witnesses are not always candid, nor experts always wise. And the individual case itself may present such baffling perplexities that it imposes not only on judge and jury, but on the most learned professors in the land.

In Erichsen's day, diagnosis was uncertain in all the disorders at present called the traumatic neuroses. Now, most of them, such as neurasthenia and the various trains of morbid thought which result from back-strain, can be recognized at their true value by any physician who is reasonably experienced and careful. Not so hysteria. This mocking psychosis, with its tragedy and humor, its counterfeits and its realities, its impositions and its appeals for pity, is ever on the watch to lead the unwary into error.

In September, 1899, in Norfolk, Va., the cart which a healthy farmer was driving was struck violently by a trolley car. The man was for a moment prostrate on the roadway, but whether he was thrown out or had jumped out was one of the questions which perplexed the jury. At any rate, he walked to the sidewalk and then swooned. He was carried to a neighboring house, where he had a series of convulsions. The bystanders, strong men, tried to restrain him, but he threw them off. He then fell to the floor in such a way that only heels and occiput touched it. And in this strange posture, with body arching toward the ceiling like a bow, his frame was shaken during several minutes by violent trepidations. He was finally carried to the hospital, apparently unconscious. No evidences of physical injury were found. But the next day he complained of pain down the whole right side and there were twitchings of the face and arm. A few weeks later he became deaf and dumb and shortly after that lost the use of the right arm and the right leg.

In this condition he was brought to court, eight months after the accident, the most important witness in his suit against the street railway company. There never was a fairer trial. Opposed experts coincided in the view that the plaintiff had received no injury of important organs and that his dramatic symptoms were the physical expressions of idea. It was a tribute to the dignity of honest experts that the judge, in the face of the exhibit, listened calmly to this testimony and that the jury did not laugh out loud. For the poor man seemed sitting in the shadow of the tomb. Emaciated, his face agitated by constant twitchings, his whole right side inert and powerless, hearing nothing, uttering no sound, getting his questions on slips of paper and writing the answers with the left hand (an accomplishment acquired since his illness)—he looked the leaf about to drop, the very essence of decay. Optimist indeed who could believe in his rehabilitation.

The jury disagreed, mainly on the negligence, and the case was settled a few months later out of court. The man recovered, not all at once, but gradually. He now hears everything, and, if his wife is to be believed, talks too much; his muscles have regained their power and, when not busy on the farm, he ferries passengers across a little river in the county of Princess Anne. So the doctors, all of them, were right for once, for hysteria and nothing else can explain a case like this.

As a psychological proposition, this strange malady more than demonstrates the influences of mind on matter—it establishes the dependence of all voluntary expression on idea. It can disrupt mental and physical unity as completely as the most destructive injuries. Its dark shadows flitting in the subconsciousness corners of the mind may stimulate to increased function, or so far suppress function that the affected organ is left without its purpose. Hypersensitiveness, which soon is pain, to light, to sound, to smell and taste, to feeling, may all be products of hysteria when the disorder whips up function; when it paralyzes, the victim must get along as best he can until his sensorial servants come back to work. In the sphere of motion, twitchings, tremors, contractions and even convulsions, bear witness to excess of function; paralysis, to loss of it. These functional perversions, these idealistic symptoms, are cast in the same mold as those of structural disease. But they carry with them tell-tale differences of form and arrangement which permit their true nature to be recognized. Various and many are the hypotheses to explain the psychological enigma. For its last analysis it needs the genius of a Plato. For working purposes, perhaps the theory of Charcot is the most acceptable. He compared the genesis of traumatic hysteria—which alone concerns us here—with the mechanism of hypnosis. The jar, the blow, the fright, like the passes or the artificial aids of the hypnotist, create disorder in the mind, dazing it and reducing it to extreme impressionability. Then follow the suggestions. Verbal from the hypnotist, to the hypnotized victim of the casualty they come from the circumstances of the accident, or what follows it, or from the victim's mind itself, as it reflects on injuries he has seen or heard of resulting from similar disasters. Thus is determined the symptomatic type. Little by little the symptoms spread and deepen—they rarely reach their full development at once—until at last, the patient, sound in wind and limb, may become as inert a mass as ever wheel-chair carried.

As important as the accident itself, or even more so, are the circumstances which follow it. Injudicious sympathy from friends, fears felt by physicians not wise enough to keep them to themselves, the solicitous exaggeration by attorneys and the patient's perception of the financial possibilities of his wrongs, all give new tentacles to the morbid ideas, which burrow deeper among the roots of rational conduct. Left to a physician versed in psychic medicine and rich of conscience, with damage claim thrown out the window, there are few cases of traumatic hysteria, taken at the outset, which a month of vigorous treatment would not cure. But, with the demands of legal procedure ever imminent, such a course is never possible. In Germany and other countries which maintain parental protection of the injured, conditions are even more unfavorable. In these countries, the injured workman is placed on an allowance of money, graded in accordance with his earning, which continues to be paid as long as he is incapacitated. This robs the patient of his spur to effort and tends to prolong the mental instability. As a result, in these countries, or at least in Germany, traumatic hysteria is more protracted and rebellious than it is with us. With us, sooner or later, the case is finished. It may be years before the final card is played; but some day the game is over and the hands are on the table. And then, for the first time since the accident, the injured person has a chance to regain his health. Before there was no chance. For, with the persistence of symptom-inducing suggestions, inseparable from litigation, it is practically unheard of, if not impossible, for a plaintiff to improve in any essential particular before the release is signed or the court-room doors have closed upon him for the last time. This helps to make hysteria the most difficult disease of any found at law of satisfactory settlement out of court.

At the outset, the surgeon for the company, thinking the case is one of temporary shock, reports favorably and the claim agent makes offers of small sums. These are rejected; the plaintiff's physician has seen such symptoms aggravate with time. The attorney feels a conscientious duty toward his client and must know the way things are going before settlement is thought of. While they all thus solicitously wait, the gloomiest fears are realized. Paralysis sets in. By this time the dangerous character of the case dawns on the defendant. Head surgeons and neurologists are sent. These report the facts which usually are conspicuous enough. The patient gets still worse. All chances of settlement on any reasonable basis are now gone and the case finds its way to court. Once in the court-room, the patient is at the acme of all the symptoms. Paralysis, insensibility to pain, convulsions, loss of special senses, all make profound impressions on judge and jury. The medical opinions are too often flatly contradictory; and the jurors, thus deprived of the advantage of special knowledge, judge for themselves from what they see.

The verdicts are always large. None too large, perhaps, as actual amounts, in view of the suffering and delays the plaintiffs have gone through. But excessive when compared with the amounts paid for other injuries, more modest in their symptoms, but with far less hopeful outcome. A young girl with hysteria can generally secure a higher compensation in the courts than a working man with some lifelong disability. The amounts thus unjustly graded may indicate that juries can not grasp the dramatic power of idea; or else that they believe that symptoms conjured up from subconscious depths are even more persistent than those of tangible causation.

In strong contrast to the verdicts is the fact that hysteria from injury, in America at least, is cured in nearly every case. Such is my personal conviction,[1] based upon information obtained about the plaintiffs after the suit is closed. Into a detailed examination it is rarely possible to go. For after the trial these individuals, with surprising frequency, fold their tents and silently steal away. Those that remain within a reasonable radius rebel at the idea of reexamination. They seem to resent their recovery. A young man who was injured in one of the terrible wrecks occurring near New York a few years ago, lay in bed for two years with hysterical paralysis, awaiting the trial of his case. There were two trials. At each of them he heard, from his stretcher, his experts say his injuries were permanent. In spite of that he was up and walking freely and was commuting to his work, as he used to do, within eighteen months of the last trial. But a request, prompted by the writer, for permission to reexamine him, brought a response to the effect that "no information would be vouchsafed which could in any way be used to prevent others who had suffered as he had from being less generously compensated."

From such information as is obtainable, it would seem that full functional recovery is the rule. The women who were cripples often marry, the men return to work. But their assumptions or resumptions of activity are often slow. The patients may be well again in a few months. But the miraculous and instantaneous recoveries, such as we

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[1] In "Diseases of the Nervous System Resulting from Accident and Injury," Appleton, 1906, the writer presented the after histories of a number of cases of litigated hysteria. Since then he has added many to the series.

hear of in the faith cures, or such as corporation partisans maintain follow quick on payment, do not come within the range of medical experience. It is always several months, sometimes a year or two or maybe even longer, before disabling symptoms disappear.

The farmer whose case has already been described suffered pain and disability for a year after his suit was finished and it was four years before he recovered speech and hearing.

Litigation permits no let-ups in the disease creating suggestions; and the longer the litigation period, the longer, other things being equal, the time required for cure. In the case of a young man injured in Washington, D. C., there were eight years between the accident and final verdict. During this considerable fraction of his life, the plaintiff was glued to his chair, the victim of paralysis from idea.[2] I am still confident of his recovery, though even now, eighteen months after the finish of the legal contest, he has not begun to walk.

The mechanism of recovery in these litigated cases is different than in the ones reported from the shrines of healing. In these latter, the priests make new suggestions, getting at the soul through anticipation, faith and religious fervor. In traumatic hysteria, the cures take place, not so much from fresh suggestions as from removal of those which worked the injury. New springs of action are not tapped; but the stones which blocked the old ones are one by one removed. Once the case is settled, the attorney's sympathy becomes homeopathic in its dosage; the physician abandons the contingent fee; family and friends, worn out by watching and satisfied at last that the patient will not die, resume their wonted occupations. The invalid is left, more and more alone. Under the fillip of neglect, the fixed ideas show signs of weakening. The patient reflects less and less upon his injury and begins to see, in the distance, perhaps, but every day more clearly, the smiling visage of Hygeia. His interest now is to regain his health and enjoy his money, as before it was to stay ill enough to get it. Little by little, he regains his balance and begins to hobble about the room. New trials and achievements add to his confidence, though he has occasional relapses. He gets out on the street and finds himself more capable than they ever let him think he would be. Then under the stress of some emotion, or forced by some sudden danger, the part paralyzed springs into pristine being; and soon after he resumes his work.

It has long been held that such cases are the products of voluntary creation and that the hysteric is an actor and a fraud. Such a view is surely wrong. No actor can ever equal the mimetic powers of this wonderful psychosis; and even if the hysteric is a fraud, who, at times, is not? The disease reflects, to some extent, the normal nature of its victims; but it reflects still more the environment in which it is born and lives and dies.

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[2] Physicians on both sides agreed in this diagnosis.

POSTSCRIPT

After this article was in type and the proof had been returned to the editor there was received from the plaintiff's attorney in this action the following letter, written by the plaintiff's wife:

WASHINGTON, D. C., April 26th, 1909.

My dear Mr. S:—

I fear that I am too happy to express myself intelligently, but you can understand the cause when I say Mr. P. has walked and it came about from a fright produced by the falling of plaster from the ceiling at three o'clock in the morning. Of course we were all sound asleep and when the crash came, I thought some one had bursted in the door and I went into hysterical convulsions and Mr. P. found himself several feet from the bed. He is very weak, but the Doctor says that he thinks he will gradually regain his strength as the sensibility has returned to his limbs. Oh, we all are so supremely happy and I feel sure that the Lord in his own good time will restore my boy to health.

Very respectfully,
MRS. V——— P———.

NOTES ON CERTAIN PHILOSOPHIES OF THE DAY

By ALEXANDER F. CHAMBERLAIN, Ph.D.

ASSISTANT PROFESSOR OF ANTHROPOLOGY IN CLARK UNIVERSITY, WORCESTER, MASS.

I. *The Rule of the Dead.*—M. Le Bon, himself now in the other world, would have it that we are suffering inutterably from a sort of universal *mort-main.* There is but one real case of majority rule on earth, that of "those who have gone before." Our masters and rulers are neither the select few among the living, nor the many-headed people, but the great hulking mass of the dead.

With *de mortuis nil nisi bonum* goes *e vivis nihil boni.* We praise the dead with our living tongues and let their inanimate hands act for us. Our thoughts, no less than our bodies, are heirlooms from the departed. Like the savage, we hear the dead whispering by the rivers of life and speak their words after them. We bear the burden of their sins; we reap the harvest of their mistakes and their calamities. Paul, the apostle, is not the only one who had the right to say "I die daily," for all men and women are in uninterrupted intercourse with the dead. Even children, just beginning to live, are schooled with dead languages. The old, in their second childhood, are counted already dead. Youth, so full of life, is taught the art of war, adding, by national command, to the number of the dead. Only when dead are the races that were here before us, like the Indian, "good."

Yet many great ones of mankind have longed for emancipation from the rule of the dead. Some adventurous psychologists hold out the hope that some day we shall control the past instead of being absolutely at its beck and call as we now are. The racial and the individual past shall both be ours and memory-guided progress will speed us on to the destined goal. Then, indeed, shall "old men dream dreams" and "young men see visions," and all who see in sleep, like Mahomet, shall see truly. Fear of the unconscious and dread of the past shall be lost in the conscious control of the experience of other days, of times gone by. Then shall they be, as we have fondly imagined them hitherto, the "good old days of yore." No longer shall we be the living tombs of the dead past that will not bury itself; no more phosphorescent merely with the immemorially defunct. We shall then have life, and life more abundantly.

II. *Mutability.*—Everything changes. As the old Greek philosopher said, flux is the very nature of things. Flora, fauna, races of men, civilizations, institutions, customs and habits, beliefs, ideas and ideals, are in eternal metamorphosis. Schrader tells us this to-day as did Heraclitus long ago. The twentieth-century idea that its culture and its creations will endure may be false, as have been the ideas of Egyptians, Greeks and Romans. The conception of stability is an illusion. All passes and repasses.

Egypt for millenniums has been only a gift of the Nile renewed by its floods. The heroes of Homer are brigands to-day. The Roman Cæsar has become a Pope. Spain died when the Indies were born. The cliff-dwellings of Arizona and New Mexico speak of things past and gone. The Negritos, the Bushmen, the Ainu, the Lapps, the Eskimo are being driven to the wall. The fate of the American Indian is partly sealed. The Aztec is a peon; the Peruvian a cargador. The Beothuk and the Tasmanian are already gone. Britain is saved from being an insular Labrador by the Gulf Stream. Bordeaux survives only through its vineyards.

With the ebb and flow of industry and manufactures, villages, towns and cities spring up like mushrooms. Others have disappeared like the melting snow-flakes. The forest vanishes and the sea is encroached upon. Holland reclaims a lost country, America reanimates a desert. Rivers and lakes are dried up and mountains are hewn down.

But, after all, there is an illusion about this flux itself. To remind us of its relativity, the Fellah, direct descendant of the most ancient Egyptian, keeps watch beneath the pyramids. Before him have passed, as the ages came and went, Libyan and man of Punt, Sardinian and Hebrew, Persian and Babylonian, Greek and Roman, Arab and Turk, Frenchman, Englishman and American. And amid all their notable mutations he has remained practically the same. He still waits for the stirring of the waters.

III. *Imitation.*—Wise men before Solomon said "there is nothing new under the sun." And in all they have thought, said, done or dreamed, the ignorant in all times and among all peoples have corroborated the sages. The great majority of the wise, too, have labored zealously at the same task. To-day, Tarde tells us, imitation is everything.

Art is imitation of nature and nature imitation of God. God imitates himself. Civilization is mimicry. Genial repetition is the sum and substance of great knowledge and deep wisdom. Ignorance is gross imitation. Life and death are both imitative. By imitation childhood learns, youth hopes, manhood forgets, old age despairs. Heredity itself is imitation. Both the individual and the race have acted, "as if its whole vocation were endless imitation."

How hard it is for man to do otherwise than his fellows are doing or have done! To repeat is so much easier than to invent. To borrow than to create. To follow than to lead. To stand with the many than to fall alone. Fortunately for mankind, evolution has set limits to the tide of imitation:

> There's a divinity that shapes our ends,
> Rough-hew them how we will.

IV. *Misoneism.*—If we believe Lombroso, *misoneism* or *neophobia*, "the hatred of the new," is one of the most deeply ingrained characteristics of man. Progress occurs only when there is a break in the neophobic series. The leaders of mankind are not the many who imitate, but the few who do new things, or think them. And many of these put new wine into old bottles—the makers of new vessels are rarer still. And woe unto those who, with new wine, break old bottles! The blood of such has been the seed of civilization, of the church, of science. Genius, prophet, saint, hero, sage are slain, and the world moves on a little, forgetting even to raise a monument to its great dead. Death baptizes new life: The fall of the few wise inspires a little the ignorant multitude. A martyr means more than a school or a church. On the dead hero springs up the living faith. The doctrine of "the good old days of yore" comes easily to man, who is naturally uncomfortable in the presence of the new. Yet the monotony galls. To take the kingdom of heaven by violence affords relief.

Reforms come from the acts of the few who destroy the old, or through the deeds of the many who slay the innovator. Death or ignominy for centuries has awaited him whose message is: "Behold! I make all things new!"

But not so forever! Slowly, but surely, men are learning wiser and better ways of hating and destroying the new, of preserving and continuing the old. The cessation of blind leadership of the blind means the orderly development of human society. Revolution is giving way to evolution. The old turns naturally and peacefully into the new. War will soon be as unhuman as murder.

An age is near in which we shall no longer imitate the errors of revolutionary epochs. We shall grow into the future by growing out of the past.

In that happy time we shall wonder that their bards could have sung the Celts into vain and pernicious wars; that her philosophers could have desolated Greece by making constitutions for her cities; that soldiers could have brought Rome to vice, luxury and decay; that priests could have led Judæa to reject Jesus for Barabbas; that gold could have brought Spain, once monarch of all the world, to nocuous desuetude. We shall know evolution and act in its spirit.

The philosopher will be content to see the passing of his own physical and mental minority before attempting to lord it over the bodies and souls of his fellows. The statesman will not venture to propound constitutions for states before he has learned to know the laws of his own life. The soldier will not longer yearn to reenact on a grand scale among the nations the war of members and of parts which his own body and mind sustain in youth, but will seek to overcome it in the body politic as in his own organism. Thus will be verified the saying of Scripture: "He that ruleth himself is greater than he that taketh a city." The priest will as gladly serve, as once he ruled, the state. He will rejoice more in being a servant of God than a ruler over men.

V. *Struggle.*—Man's struggle with the elements has been even more successful than that with his fellows. The hours of final triumph have often been delayed by his own carelessness and dishonesty alone. Beginning with the arrow he won the all-encircling air, with the dug-out, the inhospitable sea, with fire, the inclement sky, with the digging-stick the unyielding earth to his service, or, at least, to his unhurt.

Since his first conquest—as Gallouédec suggests—of the hill-side and of the little mountains, he has become master of the plains, and now morasses and bogs, deserts and huge mountains are fast yielding to his sway. He lords it over unfathomable chasms, dizzy heights and wind-swept ocean. He makes the desert blossom as the rose, and from the very bones of earth coins and fashions things whose beauty is everlasting. He has harnessed the lightning, housed the sunbeam, and both have become the servants of art and of science. Things terrible to his eye and his ear, nay, that shook him to the uttermost depths of his soul, when he first trod the earth, are his familiars now. He has made nature his servant instead of remaining her slave. Gallouédec hardly exaggerates when he says that from the first man to the Frenchman or the Englishman of to-day is not a whit less than the distance separating the formless block of marble from the statue produced out of it by the genius of the artist. And the future bids fair to outglorify the past. The conquered earth, once the mere hiding-place of the savage, or his prison, is becoming more and more his home. Nature, who once held him in bondage, after being his servant, turns to colleague and friend. With the passing of war and the lust of human slaughter man is beginning to feel at home in the world and in the universe. And now the empire of the sky is beginning to be his. The future years will see the results of the leisure which progress in man, who alone of all creatures possesses the power to utilize the past and to discern the future, has made possible. Man will live and labor, transform and create in the full sense of his partnership in all about him, his slaves and servants having become his friends and co-laborers in the evolution of the cosmos. He will outdo Ulysses. He will become a part of all that he has met, and all that he has met will have become a part of him. Struggle will be succeeded by togetherness.

FORMATIVE INFLUENCES

By Professor G. J. PEIRCE
LELAND STANFORD JR. UNIVERSITY

WHEN I was a boy in New England it was the fashion to decorate the windows of the drug-stores with masses of huge deep blue crystals of copper sulphate—blue-vitrol or blue-stone. These ornaments have vanished now, even from the country drug-stores. Their places are taken by electrical toys, patent medicines, even animals. But these lumps of translucent crystals always interested me. Their composition is simple; sulphate of copper and water are their sole constituents. The sulphate of copper is itself a dull gray powder, not a crystalline substance at all; but if water is with it, it becomes blue, colors its solutions blue, and crystallizes in very regular form. The color and the form of these crystals depend, therefore, upon both water and copper sulphate.

The boy who plays with blue-stone, dissolving it in water and then recovering it again by crystallization, thus doing for fun what the freshman in a chemical laboratory does because he is directed, learns that the crystals will be large or small, few or many, according to the speed with which they form; large and few if they form slowly, small and numerous if they form rapidly. This is equally true of sugar, common salt and other crystalline substances. We see, then, that circumstances as well as substance have to be taken into account. Although we can not have crystals of this particular kind unless we have the sulphate of copper, neither can we have them, even with an abundance of the salt, unless we have water also. The water must not be in excess, lest the copper salt remain in solution; nor deficient, lest it remain amorphous. It must be exactly proportioned in quantity if the salt is to arrange itself into bodies of definite form. The size and the number of these bodies depend upon temperature, dryness of air, any circumstance, in fact, which influences the rate at which water evaporates from the solution.

Although the number, size and even the formation of blue-stone crystals depend upon circumstances, and will vary according to circumstances, circumstances can not make blue-stone crystals exactly like the crystals of other things. The crystals of common salt have characters which identify them to the eye and mind of the crystallographer. These characters, we say, are inherent in the substance itself. This may be true actually as it certainly is true practically; but a scientific man might be found who would hazard the opinion that common salt, which crystallizes in square plates with hollowed surfaces under the conditions which we know, might crystallize in another shape or remain amorphous on some other planet where the force of gravitation, the composition and pressure of the atmosphere, and other factors of its environment, would be different from those constituting our environment on this earth.

Students of the natural sciences reckon with circumstance as well as substance. Physicists and chemists know this, and work with a conscious realization of this fact. Of the biologists, none more keenly realize the significance of circumstance to the organism than physicians and surgeons. Sociologists dispute whether heredity or environment determines the qualities of the man. Many botanists and zoologists meantime are discussing fine-spun theories of heredity based on the infinitely more finely spun microscopic structure of plant and animal cells, devising a scientific vocabulary which breeds dictionaries while it veils our real ignorance of the facts concerned.

The thorough study of mankind, or of any other living or lifeless thing, involves a study of the substance of the thing and of its environment. Study of the simple substance of blue-stone and of common salt is comparatively easy; but the bodies of living things contain and probably consist of many substances, few of which are as simple as blue-stone and common salt. Definite chemical compounds, many of them complex and unknown, constitute the bodies of living things. These compounds possess their own properties, their own characteristics, inherent if you choose. Their behavior controls if it does not constitute the behavior of the living thing. But this behavior depends on circumstance, is controlled by environment. The living thing, human or vegetable, can not be known till its environment as well as its substance, and the influence of the one upon the other, are known.

The chaplain of this university, coming to my laboratory one day, was surprised by some machinery which he saw there and asked its purpose. I told him that I was proving that, if you took a slum-child early enough, you could make a decent man of him. My friend protested that I was omitting many links between the plants of my experiments and the less fortunate of the human race. While frankly admitting this, a scientific man may still believe that he can contribute to such proof by using guinea-pigs, or rats, or even plants, as the objects of his experiments. These experiments are designed to furnish information about the circumstances, the influences, the factors of the environment, which affect behavior.

We see the various factors composing our environment directing the movements of our fellows. A bright light or an unusual sound at once attracts notice, may even draw a crowd. The absence of light, generation after generation, has cost cave animals their organs of vision. Who can say that the perpetual noise of our cities will not induce changes in the nervous balance, if not in the organs, of men?

The force of gravity, which enables a man to stand erect, defeats the unbalanced efforts of the baby learning to walk; it directs the growth of root and shoot from the sprouting seed; it forces organs and organisms to carry a very large proportion of their own weight or perish. When plants and animals live in water, over seven hundred and fifty times as much of their weight is carried for them as if they were growing in air. When plants are supported on trellises, or grow on trees, their mechanical strength, the development of their supporting tissues, corresponds to the lessened load. The buoyancy of the water and the mechanical support of trellise or tree, opposing the pull of gravity, modify and reduce its formative influence.

If we compare the great brown kelps growing along the rocky parts of the Pacific Coast, attached by hold-fasts to the bottom, floating upward and along the surface of the ocean till they become the longest plants known, with land plants, we find only some trees and such vines as the rattan at all approaching them in length. But in structure and in mechanical strength, what a difference there is! Bring the seaweed ashore and try to stand it up; take the vine down from its support; neither will be able to sustain its own weight. The force of gravity opposed, in the one case by water, in the other by the forest trees on which the rattan grows, has not exerted its full influence on either. The tree stands, and its trunk is composed of mechanically strong tissues, in part at least because of the pull of gravity only feebly opposed by the air.

Experiment proves the formative influence of gravity. The English gardener who trains his peach trees on the southern face of a wall knows well that such trees are mechanically weaker, though more prolific, than other peach trees growing unsupported in the same enclosure. The delicate stalks of the blossoms of apple, peach or prune, thicken and strengthen as the fruit sets, grows and ripens, the increased pull of gravity stimulating the living stalk to meet the greater strain by greater strength.

When we take into account the fact that the force of gravity acts constantly, that though we ordinarily ignore it or take it unthinkingly for granted (as we do the quality of our milk), it is an unchanging force, the same night and day, from season to season, from cycle to cycle, we begin to realize that it must exercise a formative influence of the utmost importance on all living things, stimulating the growing plant and animal to develop an adequate skeleton and to attain a balance of parts which will tend to stability.

Water opposes the force of gravity by buoying up, and carrying so large a fraction of the weight of, the creatures living in ponds, streams and the sea. In addition, it has a positive influence of its own. We are used to the directive influence which causes the wild creatures of field and forest to make the runways between den or nest and water-hole so charmingly described by Mrs. Austin. Every trout-fisherman has seen the roots of alder and willow growing from the bank into the stream. We are accustomed to having our house-sewers stopped up by the roots that *will* grow into them, though there is much more room outside. But the formative influence of water is not so obvious. Yet when we think of the creatures, plants and animals, of arid regions and of well-watered ones, we perceive certain differences. When we realize that water is formed, or is the surrounding medium, in almost every chemical reaction which takes place outside the living body, and in every chemical reaction within the living body, its importance is evident enough. The shape, size, structure and covering of every animal and plant are influenced by the ease with which water may be obtained and held. All land animals and plants lose water from their bodies by evaporation; submersed aquatics do not. Land animals and plants ordinarily get water from the earth, from depressions in its surface or from its soil, and only through those limited parts of their whole bodies which touch the water; but aquatics can take it in through their entire surface. If a land plant or animal takes in water only through its roots or its alimentary canal, there must be some system for distributing the water to all the parts of the body; but this is not necessary in aquatics. The differences in structure and form between land and water organisms is, then, partly due to their relations to water. The differences between the tadpole and the frog, between the submersed and floating leaves of the water-buttercup, between the swimming sperm of moss and fern and the wind- or insect-borne pollen of the higher plants, these differences are in their relations to water, in the degrees in which the formative influence of water has been unopposed by other factors.

Before turning to other formative influences, we should realize that the force of gravity acts constantly, night and day, uniformly, age after age, and it is impossible either to eliminate it in experiments or to conceive of its operation ever being or having been interrupted in nature. Water also is constant and uniform and unavoidable; for until water ceases to be a necessary component of the living protoplasm of the plant and animal body, until it becomes something else than hydrogen and oxygen in the proportion of two to one, we can not conceive of its being eliminated, by exclusion or substitution, in experiment, or of its absence in nature. If water is absent, life is absent. This is not true, however, of other influences, material or energetic, which affect form and substance, as well as the direction of growth or movement. These influences may be temporary.

Light is not a necessary condition of active life. It comes and goes, day and night. In the extreme northern mid-summer the sun never sets; the winter is dark and gloomy. In spite of the lack of light, however, life goes on in the winter darkness provided sufficient warmth is attainable. Nor is light uniform, for though the total seasonal light-fall may be, like the total seasonal rainfall, a moderately uniform quantity, yet we know that the light which reaches our eyes and plays on field and forest varies almost from moment to moment, as a wisp of cloud, a trail of smoke, or a bird or butterfly, passes between us and the sun. Yet with all this variation in quantity from day to night, and even from moment to moment, there is no variation in quality. The composition of sunlight, as it reaches the earth's atmosphere, is the same age after age; its red, yellow, blue and other rays fall upon animal and plant in similar proportions. Until the source of light changes, until the composition of the sun becomes altered by the exhaustion of this or that substance, the quality of light must continue the same.

The leaves, stems and flowers of our household plants turn toward the window. Plants growing under a hedge turn out to one side, if they are able to bear the shade long enough to get out of it. In the early morning, or toward sunset, one can often see the leaves of weeds all turned eastward or westward, according to the source of light. These are familiar instances of the directive influence of light, an influence which changes with the direction and the intensity of the light and is dependent upon some, not all, of the rays of ordinary daylight.

The formative influence of light is no less real and definite, although not so generally recognized. It determines whether a plant shall be stocky or straggling, short or long. Greenhouse men speak of spindly plants unduly shaded as "drawn." The ordinary broad, brown bean —Windsor, or Horse, or Spanish—sown in quantity in the vegetable gardens of those parts of the west where the paths of the padres lay—correspond in height quite as much with the light they receive as with richness of soil. If sowed too closely, each plant over-shading its neighbor, they grow in the same length of time to nearly double the height of others solitary. Young pines in too close stands are tall, slender, sparingly branched. The low stature of some of the plants of mountain-tops is due not merely to crushing snow, brief growing time, and chilly nights, but also to the greater brightness of the light which falls on them than on the floor of the valleys below.

Thus the vegetative parts are affected quantitatively by the quantity of light which reaches them. Stem and leaves reach their ordinary dimensions only under ordinary illumination. There are structural differences between the sunned and shaded leaves of wild plants. The beech offers the best known case.

Eastern greenhouse men spend anxious days before Easter lest their lilies bloom too late. They can control the temperature, moisture, soil, in their houses, but beyond certain narrow limits they can not control the light. The same plants bloom at a decidedly lower temperature in California than in the Mississippi Valley and on the

North Atlantic slope. When the Weather Bureau can give as accurate measurements of the amounts of light reaching the soil in these different regions as of the temperatures, we shall see one reason for this difference. Even though flowers may be already formed, a certain though unknown amount of light is generally necessary to bring the flowers promptly to perfection. More than this, the number, size, color, fragrance and other qualities of the flowers, the number of eggs and sperm in them, even the formation of the flowers themselves, are dependent in very many plants upon an amount of light more than sufficient to maintain vigorous growth. This has been clearly shown by experiment on so many plants, simple and complex, as to lead one to think of light as a definite stimulus to reproduction. I can grow certain moss-like plants year after year in my laboratory and, according to their position, in a light or a dark place in the room, they will form reproductive organs or will remain sterile. I can do the same thing with submersed water-plants, and in garden and greenhouse the same fact is demonstrated year after year.

John Muir, in his "Mountains of California," gives the most glowing description of spring bloom which I know, where he tells of the San Joaquin Valley before it was settled. The newcomer to California to-day is struck with admiration of the great mats of color on hill-side and valley-floor. This prodigality of bloom far exceeds what one sees on either slope of the Alleghanies. Transplant the California "poppy" to any less sunny land and it degenerates; it blossoms less freely, its flowers are smaller, its petals are more sulphur or lemon than orange-yellow, its seeds are smaller and fewer. It seldom grows, still less blooms, under the shade of the live-oaks, though the open field may be golden with them. The more shade, the less bloom.

Testing this conclusion by experiment on plants very different in shape and size in their vegetative and reproductive stages, as is the case in *Sempervirens* and similar squat plants used for bedding or bordering, it has been found that the reproductive stage may be indefinitely postponed by growing the plant in feeble diffused light. Rather more light stimulates the plant to send up a stalk from its rosette of leaves, but this stalk is leafy. Still more light will induce the formation of flowers; but only when fully illuminated will the plant form perfect flowers and set good seed.

Cultivated violets are from eastern and European stock. In the middle west, in New England and in northern Europe, violets of many species form, in addition to the conspicuous blue flowers, others ordinarily concealed by the leaves. These hidden flowers are white or pale, lumpy, and closed. In certain districts in Italy, the same species of violet do not form these closed (cleistogamous) flowers. In the sunniest parts of California gardens the violets never form them. Other plants form cleistogamous flowers, but the number of these species in different regions is very clearly related to the amount of sunlight. Northern Europe, New England and the northeastern part of the Mississippi Valley have less sunshine than the great western plateau, the Rocky Mountain region, Italy and California. There are some species of cleistogamous plants on the plateau and in the Rocky Mountain region; there are more on the two slopes of the Alleghanies and in Europe. Only a species or two have been found in central California, and these live in the dim light of virgin redwood forest.

Animal physiologists have not yet shown, I believe, that the breeding-seasons of animals generally mark the reaction of these animals to external influences. There is obviously every reason why birds should not mate till the rigors of a severe winter are over. The breeding-season of frogs and toads must coincide with the season of abundant water in ponds and pools. But I am inclined to believe that where there are no seasonal differences, or only very slight ones, in light, warmth, rainfall, there are only slight differences in the habits of plants and animals. Sea-urchins, for example, like many of the sea-weeds, have no regular breeding-seasons; the changes are slight in the water which nearly always covers them. On the other hand, land animals, subject to the more pronounced changes in their habitat, have their cycles of vital processes to correspond.

Light stimulates flowers to form; it stimulates the violet to develop one kind or another according to the amount of light. Light influences the growth of leaves and stems by its direction quite as much as by its amount. The direction from which light comes determines also where and how a plant part shall form. Vertical leaves, like those of onion and eucalyptus, are alike both structurally and superficially on the two sides. Horizontal or oblique leaves evidently differ on their two faces. Light has much to do with this difference. The reproductive stage of the fern is a small, flat, leaf-like plant, usually growing closely applied to the soil, its upper side lighted, its under side dark. If, for purposes of experiment, the light is made to come from below or from one side, instead of from above, the reproductive organs form, as before, on the side away from the light. They always form on the dark side, whether this is above or below, or more or less vertical. Light and not gravity is here the formative influence, stimulating the reproductive organs to develop and determining by its direction the side of the plant which shall bear them. Sometimes there may be a conflict of influences. If there is no dark side, because the plant is equally illuminated on both sides, the reproductive organs will form equally on the two sides.

If the direction of illumination determines where the reproductive organs of these small fern-plants form, may it not also influence the shape of the plants themselves? It may. There are many small leaf-like plants, allied to the mosses and ferns, growing against soil, or bark, or rock. Their structure is dorsi-ventral. When these little plants first start, they are erect and cylindrical; the divisions of the fertilized egg-cell from which they spring are at right angles to the source of light. Presently, however, these little cylinders tip over and, the light still coming from above, they spread out at right angles to it. Thus the erect cylindrical form and radial structure soon give place to prostrate leafy form and dorsi-ventral structure. It is now known in at least one case, and suspected in many others, that if the little plants can continue to receive light symmetrically, their form will be correspondingly symmetrical. By slowly revolving them for months after sowing, so that they were equally illuminated on all sides in succession, I have obtained plants which were as cylindrical at the end of my experiment as in the early weeks. Where the illumination was equal, the structure was perfectly radial; where it was unequal, the structure was dorsi-ventral.

This matter of bodily form, different or like in two succeeding generations, depends upon the direction from which the light comes. If the offspring have a one-sided illumination, as their parents did, their form will be flat and prostrate like their parents; but if the offspring are symmetrically lighted, they will be symmetrically formed in spite of the difference from their parents.

So far as these experiments contribute at all to the solution of biological or sociological problems they do so by indicating that like influences produce like effects on the same substance, and that, although the substance may be the same, unlike influences will produce unlike results. They make us a little more confident that the child of vicious parents, if itself sound, can be made into a much more desirable citizen if brought under influences different and better than those surrounding and exerted by its parents.

The formative influences so far discussed produce normal and healthy effects. The deformative and pathogenic influences which affect human and other animal bodies have their parallels among plants. Besides the plainly marked plant-diseases due to such obvious parasites as borers, rusts, rots and mildews, there are influences no less real, although easily overlooked.

City life is unfavorable to plants. Atmospheric and soil conditions are either bad or not bad, they are never good. One need only pass along a street in which the gas-pipes have been exposed to know that the soil is more or less saturated with stale illuminating gas. The odor is offensive. Trees rooted in soil poisoned by large or small, but always continuous doses, of illuminating gas, do not thrive. Their leaves are never the full rich green of trees in the country, the foliage yellows early and many leaves fall. Add leaky electric wires, leaky sewers, and the putrefactions going on in fouled soil, and one realizes the cause of the chronic lack of vigor of street shade trees.

The trees in yards, gardens and parks are only somewhat better, they are not entirely well. An atmosphere polluted by the products of all our fuels except wood contains active poisons, not merely inconveniences. Because there is less soot in New York and San Francisco the inhabitants speak boastingly to their less fortunate friends in Chicago or St. Louis. But the smoke problem of cities is a problem of gaseous, not solid, emanations. Smoke-consumers, so-called, add to the bearableness of urban existence by reducing one disagreeable feature. They do not in any way affect the more serious ones. The sulphurous and chlorine gases, even sometimes fluorine, escaping from the chimney-tops of the office and factory buildings, and from the dwelling houses, of a city of diversified activities, affect human, animal and plant life. Certain wild plants which one would expect to see on the tree-trunks and stone walls in towns where the air is humid, are entirely absent. They have disappeared, in fact, from European cities since the use of coal became general.

If one would have a clearer view of what the effect of these gases is let him go where they are discharged in greater proportions into the air and note the effect on the native vegetation. Wherever smelters are in operation, treating sulphurous ores of copper, zinc, mercury, plants sooner or later disappear. Forest and farm suffer and finally become almost or quite valueless. This is simple poisoning, resulting, where the dose is great, in death.

The egg of a gall-fly laid in or in contact with developing tissues, hatching a grub which feeds and grows and excretes, becomes surrounded by a growth unlike anything else which the leaf or branch would develop, a growth of plant-tissue characteristic of the particular kind of plant and of the particular kind of fly. This developing tumor is the result of the presence of the grub, of the formative influence of this parasite. Similarly, the tubercles developing on the roots of many plants exhibit the formative influence of the worms or of the bacteria without which they would not start, much less develop, as they do.

The life-experiences of all living things, and even the things themselves, are the joint product of substance and circumstance. Some, if not all, of the substance is continuous, transmitted, from parent to offspring; some, but not all, of the circumstance attending this from the beginning to the end of its existence, is continuous. In the continuity of substance and circumstance lies the basis of the likeness of succeeding generations: in the difference of circumstance from time to time lies the basis of the difference which we see between offspring and parents. For circumstance is but Emerson's synonym for the evolutionist's word environment; and environment, on analysis, proves to be the sum of the formative influences.

TRAINING COLLEGE TEACHERS

By W. B. PITKIN

NEW YORK CITY

YOUR American is quite willing to admit that his children, on commencement day, are not what they should be, but he is sure that he and his fellow taxpayers are not to blame. They support twice as many teachers as saloonkeepers. They have built all the machinery of education. Never were more kinds of schools, never better equipment. If, therefore, a college president were to sigh over the scarcity of good instructors, your American would not understand. He would say:

> You have your buildings and your professors and your students. You offer graduate work for all who would teach. You even have teachers' colleges. And I see many young men of exceptional attainments becoming college instructors every year.

And probably the college president, too, would join in his mystification, or—what amounts to the same thing—repeat "*nascitur non fit*," and fancy the shortage explained. But the machinery is not complete, as either party may discover when asked to point out the exact process of training college teachers. Suddenly it will appear that there is no such process.

Every other sort of teacher is being broken in. Normal schools are swiftly filling elementary and high schools with men and women who can manage not only their subjects but also their pupils. A teachers' college prepares its students

> for university and college professorships or instructorships in education; and for work as supervisors, principals and superintendents of schools, and as heads of academic or educational departments in normal and teachers' training schools; as well as professional training, both theoretical and practical, for teachers of both sexes for secondary, grammar and primary schools and kindergartens; and for special teachers of such technical subjects as domestic art, domestic science, fine arts, manual training, music, nature-study and physical education.

"Professorships in education," but no classes for ordinary professors who would educate! And so everywhere else. The university specialist is drilled for research and for the management of graduate classes during the years of his doctorate and later assistantship in laboratory or library. But where does the college teacher, the man who is to teach freshmen English and economics, pick up the tricks of his trade?

If he ever picks them up, it is by chance or cleverness and in spite of obstacles. The special knowledge he is to impart he gets well enough

—perhaps too well. The collegiate post is approached through the doctorate. In the later stages of this way, he is sometimes allowed to correct examination papers, lead quizes, and, if his professors are kind, even give a course of lectures. But usually this last boon is reserved for the days of assistantship, when, left to his own resources, he takes charge of a brawling roomful of sophomores. Of pedagogy knowing only the name, he sets about instructing by the method of trial and error; and the result is mostly trials and errors. The holy law of individualism locks the door against the professor who might be tempted to stroll into the beginner's class-room and help him along. But, if he were only left alone at his teaching, he might hope to pick up practical wisdom in a few years. He has not even that good fortune, though. If not by word, then by attitude, his colleagues often discourage him from becoming a "mere teacher." There is earnest in the old jest: "A college would be a fine place, but for the students." Our young instructor sees his seniors' names at the head of articles in his technical journals and they spell: "Go thou and do likewise!" At department conferences, problems of economy and research are broached, but beyond the broader question of schedules, text-books, periods and general manner of treatment, teaching is untouched: Is it because even the professor thinks his colleague *nascitur non fit,* and so dares not advise him for fear of insinuating that he is not fit? Be that as it may; pedagogy is suppressed as by a censor and investigation exalted until the university habit is set in grooves too deep to leave. And the freshman is left a foundling in inhospitable or palsied hands.

The results of this familiar unbalance are so grotesque that the writer, for one, would not believe them save on the evidence of his own eyes and ears. One instructor, whose researches have been a credit to his college, makes his freshmen learn the French for all parts of a full-rigged ship—and this, too, after he has taught several years. A scientist, with an important investigation half finished, turns his undergraduates into laboratory assistants; and, when confronted by a complainant committee, is honestly thunderstruck to hear that nobody is getting anything out of his courses. A mathematician of international repute lectures to his beginners on the great controversies of the geometers since Descartes. And a student assures me that, in the second semester of freshman German, he was set to translating "Macbeth" into the tongue of Goethe.

Let us not berate anybody for such absurdities, least of all the teachers themselves. Their pedagogical ignorance is due neither to slovenliness nor to neglect, but is a more or less inevitable incident in the great turmoil through which all our educational ideals, methods and means have been and still are passing. The hour calls less loudly for criticism than for a remedy. And the sky has cleared enough to bring the latter into sight. Though the purpose of college may still be beclouded, and though there is still much fighting in the dark over the curriculum, at least two things are pretty sure: first, within fairly wide limits, it makes little difference what the undergraduate is taught in his first two years, provided he is really taught;[1] and, secondly, teaching is not a trick that any man can pick up for himself. These two facts leave us with only one thing to do—train graduate students to be college teachers.

Our normal schools and teachers' colleges have proved this possible. They are turning out excellent high-school teachers, and, if that can be done, then at least good teachers for the first two undergraduate years are makable. The difference between high school and college is narrowing. The National Association of State Universities, in its efforts to create a Standard American College, aims to "differentiate its parts in such a way that the first two years shall be looked upon as a continuation of and a supplement to the work of secondary instruction, as given in the high school." Let us restrict our problem, then, to the making of a freshman and spohomore faculty. If we can furnish this much, the rest will be easy.

There are many reasons why the normal school should not be called upon to do this for us; but the chief one is that the institution offers no opportunity for genuine apprenticeship. And without apprenticeship, training is greatly hampered, as the normal schools themselves have learned in the case of the high-school teacher. To the college, then, falls the training. The larger universities must offer it in a graduate school, and somewhat after the following manner.

1. A three-year course, of which one year shall be given over to pedagogy and two to actual teaching, shall lead to a doctorate. I trust the pedagogy needs no explanation. The two practise years, however, may. They find their defense in the axiom that the only way to learn how to teach is to teach. And they find their excuse in the fact that the young teacher is a necessary evil. An ideal college, to be sure, would have, say, a professor ordinary for every freshman class of fifteen; but not even Mr. Rockefeller is willing to finance such an institution. And not all the money in the world could make *all* college instructors finished scholars. So surely as teachers must be born and bred, just so surely must the undergraduate always suffer more or less from immature instruction. But he will suffer least if led by young men who are engrossed, not in writing a thesis, but in their class work.

The course of training I suggest should lead to a Ph.D. in order to attach the same dignity to the expert teacher that now attaches to the skilled investigator. This means, of course, a sharp break with tradi-

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[1] Not that Choctaw is just as good as chemistry, but the lower levels of all grand divisions of knowledge lie in about the same plane.

tion. The doctorate has always stood for original work, discovery, scientific attainment. It has generally been assumed that these virtues are superior to those demanded of the man who at once imparts knowledge of a special sort and shows to growing minds its wider bearings for the building of character and the perfection of culture. This is, nevertheless, pure superstition; the sooner we smash it, the sooner will business and professional men cease to look down upon teaching, and the sooner have no ground for saying that the academic career attracts inferior men. Let us frankly rate teaching as a specialty on a par with those now pursued in graduate schools; it will prove not only just but, I think, excellent diplomacy.

2. The candidate for such a degree shall specialize in some general subject. His first year shall include the elements of teaching (if these have not been mastered in undergraduate courses), and also as much special drill in the pedagogy of his elected field as is feasible. If the university can not offer the latter, an arrangement might be made whereby the student could spend his first year at an institution where the work is provided. There is no reason, though, why, after the proposed system is inaugurated, one professor from each of the freshman and sophomore departments could not find time to offer such work.

3. When, in the second year, the student becomes a teacher in the department of his choice, he shall be assigned to *full teaching work.* Perhaps an ideal apportionment would be two freshman and two sophomore sections of fifteen students each in three-hour courses, making a total of twelve hours' classwork a week. Half this amount might be preferable in the first semester of teaching. At least one professor in the department shall devote part of his time to supervising the student-teachers. He shall visit the sections as often as he deems necessary. He shall question the student-teachers about the individual men in their classes and their difficulties. At the close of each semester, he shall examine the sections himself; and his marking shall be counted in upon the term marking both of students and their student-teacher on some equitable fractional basis. (For instance, the supervisor's markings might weigh equally with the term markings of the student-teacher against the student; and the supervisor's average marking of the class might weigh equally with the student-teacher's individual knowledge of his subject in the computation of the student-teacher's total efficiency. These proportions are, of course, merely illustrative.)

4. The student-teacher shall be required to attend no classes in his last two years of work; but, he may have the privilege of so doing; if, in the opinion of the department, he will profit thereby. In general, however, the policy of the department should be to encourage wide reading, not only in his specialty but in cognate branches, the aim always being to give him his bearings in the world and make him

see things in such a perspective that he may speedily become a competent adviser.

5. If after two years of teaching, the student-teacher shall have convinced the professors of his department that he has mastered his subject satisfactorily and has developed sufficient teaching ability and has shown a character suitable for the calling, he shall be awarded the degree of Ph.D. The degree shall be given in whatever subject the recipient has taught. The method of determining ability may vary considerably, no doubt; but some combination of examination ratings and "general impression" should be struck, in any case. The student-teacher receiving such a degree shall be placed upon a preferred list of candidates for recommendation to college appointments.

What, now, are the advantages of this system?

1. It will provide the best possible young teachers. Under any system the young teacher is a necessary evil; but he is the least troublesome when wholly devoted to his class-work. And he is most completely devoted to it when in it he finds the way to a higher degree and to advancement, and when he knows his success or failure *as a teacher* is being checked up on his score-card.

2. It will permit the nearest practicable approach to individual teaching. The supreme difficulty in the way of individual teaching is the cost. Some day one or two of our richer colleges may hope to have a staff of mature men large enough to give every student a faculty adviser and a private tutor; but most schools must resign that prospect. The next best thing, however, is the small class with closely supervised instructors who are teaching without pay (or on small scholarships) in the hope of an advanced degree and preferment.

Let us see how nearly the goal may be approached. Imagine a very large college whose freshman class is, say, 1,000. Suppose one course of English is required in each semester of the first year. The English department will then have all these 1,000 students to deal with. Suppose there are in this department altogether, 12 professors and instructors (Harvard has at least 5 more, not counting her assistants). And let us assume the purely ideal condition of having a student-teacher manage only 2 sections of 15 students each. Suppose, on the other hand, that neither of the required freshman courses could be partly or wholly given by lecture. We should then have the ideal arrangement fulfilled, if each of the 12 instructors took only one freshman section and were assisted by 27 student-teachers. By increasing the class unit to 20 students, only 19 student-teachers would be called for. Does anybody imagine that a university with a college entering class of 1,000 would have much difficulty in securing nearly that number of student-teachers for at least each of the five chief departments under the terms of the system we have sketched?[2] Needless to say, could only half the ideal number of student-teachers be secured, undergraduate instruction could still be revolutionized; if in no better way, then by putting half the students in small sections one semester, and the other half there the next. With a little careful adjusting of schedules, most students would then receive close attention in two of four departments each semester.

3. It would not add one dollar to the annual budget, but, on the other hand, would actually reduce the latter by a considerable sum, inasmuch as many assistants could be dispensed with. It is impossible to compute accurately here, for the necessity of assistantships varies greatly from department to department. In the natural sciences, for instance, laboratory helpers will always be needed, however many student-teachers there are. But, in the freshman and sophomore work, the assistants in most of the departments only correct papers, hold quizes, etc.—all of which could as well be done—and better—by the student-teacher, who would have time for it and ought to learn it. If, now, we assume that only half of the assistants now employed in our leading colleges are doing such work, we shall find that our system would reduce the yearly running expenses of Brown by $2,522, those of California by $14,025, those of Harvard by $7,808, those of Chicago by $9,990, and those of Columbia by $17,500. These estimates are based upon the number of assistantships and the average salaries of the same as given in the second bulletin of the Carnegie Foundation. Half of these savings, devoted to small scholarships for worthy student-teachers, would doubtless help materially in maintaining the quality of candidiates. Part of the other half, added to the salary of those professors who supervised the staff of student-teachers, would stimulate competent men to turn from research and graduate teaching to education. At universities with good pedagogical departments, not a single new chair would have to be created; the general pedagogical work of the student-teacher's first graduate year is already offered, while the special courses for history teaching, mathematics teaching, etc., may be given by the already installed professors of these subjects. Probably every university of rank has, in each department, at least one man who can give such courses. He is, I fear, often inconspicuous, thanks to the overshadowing discoveries and books of his colleagues; but he can, for all that, be found and turned into his proper work.

4. It will hasten the differentiation between college and university. And, while these two institutions are still "siamesed," it will provide

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[2] As closely as I can estimate from the Harvard catalogue, individual training in English could be given at Cambridge, if the present staff were augmented by only 25 student-teachers, and the 11 assistants now employed dispensed with. Were the latter converted into student-teachers, the department would have to find only 14 more graduate students, in order to fulfil the very severe conditions named.

for the fairer division of effort and attention between them. Student-teachers will relieve some members of the faculty from elementary work; it will let others pass over completely into the graduate schools in the course of time. After ten years, a respectable number of student-teachers will be ready to fill purely collegiate professorships.

5. While effecting this differentiation, it will also unify college life. If it does nothing else, it will clarify the aim and policy of each department simply by concentrating attention upon teaching problems. But it may also lead to a more thorough system of faculty advisers than has yet been found feasible. There is no reason why a student-teacher, at least in his third year, could not profitably serve as personal counselor for a few undergraduates. At present, as is generally known, the faculty adviser rarely does more than talk at long intervals with his protégés, and then on nothing more than the narrower questions of electing courses. He has no time for intimacies, as he usually carries from 14 to 16 hours of lectures a week, and has from a dozen to a score of students assigned to him. If, however, there could be an instructor for every thirty or forty students in *each* of the five chief undergraduate departments, then only six to eight students would have to be assigned to a single adviser.

6. It will help bridge the gap between high school and college. A common and well-grounded complaint to-day is that college teachers are not drawn from the ranks of the better high-school teachers. The trouble has not been with the latter; there has simply been a tradition that a college teacher must be a Ph.D. and a scientific investigator—and few high-school teachers have ever entered either of these select circles. Give the doctorate, though, for mastery of college teaching; and two things will eventually happen. First, many student-teachers upon receiving their degree, will be unable to secure college posts; and so they will then turn to high-school work, against which they will not be prejudiced, as your ordinary Ph.D. is to-day, and for which they will naturally be preferred candidates. Secondly, student-teachers thus installed will not be rooted forever to their high school, for they are known to college professors; they have taught two years in college and have established something of a reputation there which will help the best of them into college chairs some day. It is also possible that a small movement from high school to college will be set up by high-school teachers leaving their work to try for the Ph.D. in the hope of getting permanently into college work. During the next decade, this movement might be considerable, were the student-teacher system generally adopted. There are many excellent teachers in high schools who could teach freshmen and sophomores infinitely better than half the young *doctores eruditissimi* now thus engaged. And among the younger of them quite a few would prefer college to high school so strongly that they would be tempted to become student-teachers.

7. It will so improve the first two years of undergraduate work that students will be much better prepared to take up courses leading to professional and graduate pursuits in their junior year. And this is what many educators, together with the National Association of State Universities, wish to bring about.

Several objections to this plan are already on the reader's lips. It will make the doctorate equivocal. It will remove the professor from the freshman, who really needs him most. Nobody will try for such a doctorate. Or, maybe the opposite; every senior anxious to get a job will rush into this line, and there will be no candidates for research. With all the younger students under young men, discipline will become lax. A student only five years beyond his freshman days can not teach freshmen. To all these and many more, I think, good answer may be given. In the meantime, if we admit that some project for training college teachers is urgently needed, this one recommends itself to trial because it can be put fairly well to the test *without cost, without change of curriculum,* and, if necessary for prudence's sake, *in only one department.*

OKEFINOKEE SWAMP

By ROLAND M. HARPER

TALLAHASSEE, FLORIDA

OKEFINOKEE Swamp, which covers about 700 square miles of territory on the southern borders of Georgia, is one of the least known areas of its size in the eastern United States. Its existence has indeed been known to white men ever since the eighteenth century, but very few persons capable of giving an intelligent account of it have ever explored it.

History

The earliest description of this swamp which we have is that of William Bartram. He never saw it himself, but passed near it in the spring of 1773, and seems to have gathered considerable information about it from the Indians and traders. In his celebrated volume of "Travels," published in 1791, we find the following description, which is such a curious mixture of truth and legend, and withal of so much historic interest, that it is worth quoting verbatim:

> The river St. Mary has its source from a vast lake, or marsh, called Ouaquaphenogaw, which lies between Flint and Oakmulge rivers, and occupies a space of near three hundred miles in circuit. This vast accumulation of waters, in the wet season, appears as a lake, and contains some large islands or knolls, of rich high land; one of which the present generation of Creeks[1] represent to be a most blissful spot of the earth; they say it is inhabited by a peculiar race of Indians, whose women are incomparably beautiful; they also tell you that this terrestrial paradise has been seen by some of their enterprising hunters, when in pursuit of game, who being lost in inextricable swamps and bogs, and on the point of perishing, were unexpectedly relieved by a company of beautiful women, whom they call daughters of the sun, who kindly gave them such provisions as they had with them, which were chiefly fruit, oranges, dates, &c., and some corn cakes, and then enjoined them to fly for safety to their own country; for that their husbands were fierce men, and cruel to strangers: they further say, that these hunters had a view of their settlements, situated on the elevated banks of an island, or promontory, in a beautiful lake; but that in their endeavors to approach it they were involved in perpetual labyrinths, like inchanted land, still as they imagined they had just gained it, it seemed to fly before them, alternately appearing and disappearing. They resolved, at length, to leave the delusive pursuit, and to return; which after a number of inexpressible difficulties, they effected. When they reported their adventures to their countrymen, their young warriors were enflamed with an irresistable desire to invade, and make a conquest of, so charming a country; but all their attempts have hitherto proved abortive, never having been able again to find that enchanting spot, nor even any road or pathway to it; yet

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[1] According to Dr. William Baldwin, Bartram confused the Seminoles with the Lower Creeks.

> they frequently meet with certain signs of its being inhabited, as the building of canoes, footsteps of men, &c. . . .
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> It is, however, certain that there is a vast lake, or drowned swamp,[2] well known, and often visited both by white and Indian hunters, and on its environs the most valuable hunting grounds in Florida, well worth contending for, by those powers whose territories border upon it. From this great source of rivers,[3] St. Mary arises, and meanders through a vast plain and pine forest, near an hundred and fifty miles to the ocean, with which it communicates, between the points of Amelia and Talbert[4] islands; the waters flow deep and gently down from its source to the sea.

About this time the swamp began to appear on maps, though often located far from its true position, and with the name spelled in a wonderful variety of ways. On old maps of Georgia preserved in the Library of Congress the following variations in spelling can be found: Ekanfinaka (1790), Akenfonogo (1796), Eokenfonooka (1810), Oquafanoka (1818), Oke-fin-o-cau (1818) and Okefinoke (1831). The last agrees pretty well with the pronunciation used by people living in the immediate vicinity at the present time, who commonly speak of the swamp as "the Okefinoke" (leaving the e's silent or nearly so). The name is said to be derived from Indian words meaning "trembling earth," alluding of course to the boggy nature of the swamp.

After Bartram nothing of importance seems to have been learned about this swamp for three quarters of a century. Dr. William Baldwin, the botanist, who resided at the nearest seaport, St. Mary's, from 1812 to 1814, wrote to his friend Dr. Muhlenberg, of Pennsylvania, on February 26, 1814, of having just been on a short botanical tour which "extended to within about twelve miles of the celebrated Okefanoka Swamp, at the head of St. Mary's" River, but he seems never to have approached it any closer than that. The description in Rev. George White's valuable "Statistics of the State of Georgia," published in 1849, is copied from Bartram, the principal difference being that the name of the swamp is there spelled Okefinocau. The boundaries of the area, however, are located more accurately on White's map than on some of later date. In "Historical Collections of Georgia," by the same author, published in 1855, is a shorter description of the swamp, from the same source, and the name of it is spelled "E-cun-fi-no-cau."

Probably the first white men, other than hunters, to explore the Okefinokee were Gen. John Floyd and his soldiers, who are said to have

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[2] At this point in the German edition (published in Berlin in 1793) the editor, E. A. W. Zimmermann, inserts the following footnote: "Dieser Sumpf ist unstreitig der *Ekanfonoka Swamp* unter 30° der Breite; er nimmt aber auf Purcel's Karte mehr als Einen Grad ein."

[3] (Bartram's footnote.) "Source of rivers. It is said, that St. Ille [Satilla], St. Mary, and the beautiful river, Little St. Juan [Suwannee], which discharges its waters into the bay of Apalachi, at St. Mark's, take their rise from this swamp."

[4] "Talbert" is a mistake. He should have said Cumberland, as Dr. Baldwin pointed out about ninety years ago.

crossed it in pursuit of Indians during the first Seminole War, in the second decade of the nineteenth century. One of the islands in the swamp now bears the name of this general.

In the winter of 1856–7, Col. R. L. Hunter, an engineer, employed by the state of Georgia, ran a line of levels around the swamp to ascertain the practicability of draining it, and found its edges to range from about 110 to 126 feet above sea-level. This survey is said to have cost the state $3,260. His report to the governor, accompanied by a map, was filed away and almost forgotten, until unearthed in 1875 by Col. E. Y. Clarke, at that time editor of the Atlanta *Constitution*.

During the latter part of the Civil War, a number of deserters from the Confederate army found a safe retreat in the Okefinokee, and they are said to have lived for some time on an island (or perhaps a peninsula?) in the southeastern part of the swamp, which is known to this day as Soldier Camp Island.

Paul Fountain, an English traveler, claims to have been the first naturalist to visit this region. In his book, "Great Deserts and Forests of North America," published in 1901, he devotes 23 pages to it, and says among other things: "The Okefinoke has not, I think, been often penetrated; it certainly had not at the time I visited it in 1871 and 1876." Judging from the way he uses the name, he must have been pretty close to the place, but the chances are that he never saw the real Okefinokee Swamp at all. About half of his chapter on it consists of general remarks on snakes and other reptiles, and the remainder purports to be a description of the swamp; but this description differs considerably from those of all other explorers, and would apply much better to the swamp of the Suwannee River, which flows out of Okefinokee toward the southwest. Even with this interpretation, however, his remarks about the insalubrity of the region seem to be considerably overdrawn.

The first expedition for the systematic exploration of the Okefinokee wilderness was organized in the fall of 1875, by the Atlanta *Constitution* in cooperation with the state geological survey. The members of this expedition were the State Geologist, Dr. George Little, his assistants, R. H. Loughridge and C. A. Locke, Col. E. Y. Clarke and Mr. E. R. Hyde, of Atlanta, Col. C. R. Pendleton, of the Valdosta *Times* (now editor of the Macon *Telegraph*), two or three gentlemen living near the swamp, and a cook, guide and laborers. The "Constitution Expedition" remained in and around the swamp for six weeks, in November and December, 1875. A brief account of their work appeared in the report of the state geologist for that year, and a more extended description in Janes's "Handbook of Georgia," published by the state agricultural department in 1876. A few timber specimens secured by this expedition, together with several from other parts of Georgia, formed part of the state's exhibit at the Paris exposition in

1878, and a list of them in a pamphlet describing this exhibit seems to be the first authentic botanical information about the swamp ever published. The descriptions of this region in Dr. Loughridge's report on cotton production of Georgia, in the sixth volume of the Tenth Census, are derived from the author's connection with the same expedition.

Several years later, at a time when public interest in everything pertaining to the Okefinokee was heightened by circumstances to be mentioned below, Mr. Louis Pendleton, brother of Col. C. R. Pendleton, combined the historical incident of the deserters with his brother's experiences in the swamp into a story quite true to life, entitled "In the Okefenokee," which was published in six chapters in the *Youth's Companion* in August and September, 1894. (In the same paper a year later there appeared a short story entitled "Life in the Okefenokee," which must have been written by some one who had never seen the swamp.)

Until the last decade of the nineteenth century the greater part of Okefinokee Swamp was included in the public lands of Georgia, never having been claimed by private parties. In 1889 the legislature decided to dispose of the state's remaining interest in it, and in March, 1890, it was sold for 26½ cents an acre to a syndicate organized for the purpose, headed by Capt. Henry Jackson, of Atlanta, and styled the Suwanee[5] Canal Company. This company's purchase from the state amounted to about 380 square miles, and the remainder of the area was gradually acquired from private parties who held it. The object of this company was primarily to convert the timber in the swamp into cash, and the necessary surveys having been made, work began in the fall of 1891. From Camp Cornelia (named after Capt. Jackson's daughter), near the middle of the eastern margin of the swamp, a canal about 45 feet wide and 6 feet deep was gradually cut by dredges, working day and night by the aid of electric search-lights, and progressing toward the middle of the swamp (see map) at the rate of about three miles a year. At the same time an enormous ditch was dug from the same place to the nearest point on the St. Mary's River, about six miles away, by which it was intended first to float logs out to the river and finally to drain the swamp. This ditch was practically completed by 1894, but the company then found it more feasible to erect a sawmill at Camp Cornelia and ship the sawn lumber, by a railroad constructed for the purpose, to Folkston on the Savannah, Florida & Western Railway (now Atlantic Coast Line) and Bull Head Bluff on the Satilla River.

While this work was going on Capt. Jackson visited the Okefinokee about once a month, sometimes staying a week or more at a time, and

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[5] Suwannee is usually spelled with two n's, but in the official designation of this company it had only one.

exploring it pretty thoroughly. He is said to have had a more extensive knowledge of it than any other man living. As a result of his activity a good deal of information about this interesting place was spread before the public, in newspapers and otherwise. The best accessible description of Okefinokee Swamp, in Nesbitt's "Georgia, her Resources and Possibilities," published by the Georgia agricultural department in 1896, is based on his observations. Most of the above history of the operations of the Suwanee Canal Company is taken from this book, and is given in considerable detail here because the book seems to be quite rare. An abridged description can be found in Stevens & Wright's "Georgia, Historical and Industrial," a similar but much larger book published by the same department in 1901, and in Bulletin No. 5 of the Geological Survey of Georgia, by S. W. McCallie.

After the death in 1895 of Capt. Jackson, its president and most active member, the canal company suspended operations. The ten or twelve miles of canal and five or six miles of drainage ditch began to fill up with vegetation, the steamboats and dredges mostly sunk or were burned, the sawmill fell to decay, and the rails of the logging road were taken up. The property then passed into the hands of some northern lumbermen, who it is said are still planning to exploit the economic resources of the swamp, though there was no visible evidence of their work at the time of the writer's visit a few years later.

To return to the progress of exploration of the Okefinokee; Dr. Filibert Roth, at that time connected with the Division of Forestry of the U. S. Department of Agriculture, seems to have made a brief visit to the swamp in the spring of 1897. Incidental references to the two commonest trees of the swamp, cypress and slash pine, were published by him soon afterwards in Bulletin 13 (revised) and Circular 19 of the Division of Forestry.

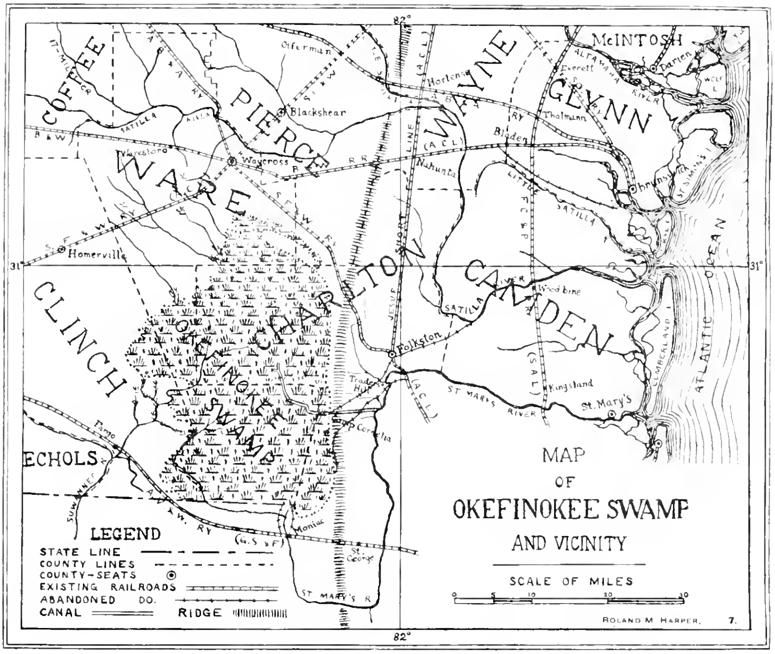
In August, 1902, the writer, in the course of botanical explorations in south Georgia, spent two days in the swamp, and considerably more time in the surrounding country. In the swamp he was accompanied by Mr. P. L. Ricker, of the U. S. Department of Agriculture, and a native guide. We traversed the whole length of the old canal in a small boat, and made a side trip on foot through the bogs to an island about two miles off the canal. Together we took about forty photographs, including all those used to illustrate this article. Brief notes on this expedition have been published in several scientific journals, but nothing like a complete description of the vegetation of the swamp has yet been attempted.

During the winter and spring of 1905–6 a party from the Bureau of Soils of the U. S. Department of Agriculture examined the soils around Waycross, and in their report, published in April, 1907, is a pretty fair description of the northern end of Okefinokee Swamp.

Having outlined the sources of our knowledge of this interesting region, it may now be described from a geographical standpoint.

GEOGRAPHY

Okefinokee Swamp lies almost entirely in Ware and Charlton counties, Georgia, about fifty miles from the coast and 115 feet above sea-level. (It will be noticed that in its elevation and distance from the coast it differs considerably from the two other great swamps of eastern North America, namely, Dismal Swamp and the Everglades.) The surrounding country belongs to the flat pine-barren region of the coastal plain, and is notable for the lack of diversity in its topography. Except in the vicinity of some of the creeks and rivers, the ground has scarcely any slope, and the channels of the smaller streams are ill-defined. At almost any point on a railroad within thirty or forty miles of the swamp one can see the rails stretching away in a straight line farther than the eye can reach, in one or both directions. The longest



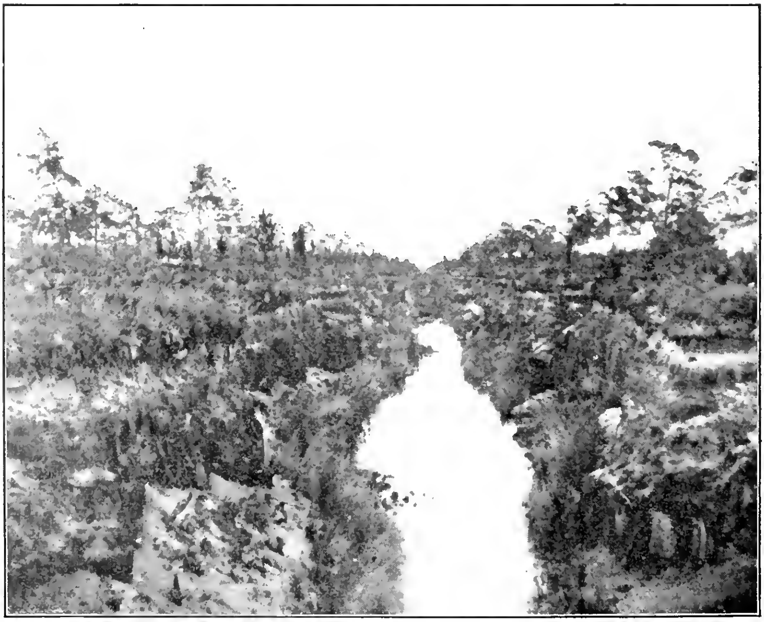
Map of the Southeastern Corner of Georgia, showing the location of Okefinokee Swamp and the ridge east of it. Compiled from county maps in the Secretary of State's office in Atlanta, a map drawn for the Suwannee Canal Company in 1897; U. S. Coast Survey chart No. 157, 1901; field notes of the author, 1902–1904; Rand, McNally & Co.'s map of Georgia, 1906, and the U. S. Department of Agriculture soil map of the Waycross area, 1907.

The abandoned railroads are shown principally because they are convenient highways for exploring the almost trackless pine-barrens on foot. The location of the islands and other details within the swamp are not given here because too little is known about them at present.

stretch of straight track in Georgia, from a few miles southwest of Waycross to a few miles beyond Valdosta, sixty miles in all, crosses the head-waters of the Okefinokee.

The geology of this flat pine-barren region is comparatively simple. The surface is a few inches or a few feet of Columbia sand, and under that is the clay, loam or coarse sand of the Altamaha Grit or Grand Gulf formation to a depth of three or four hundred feet. None of these formations are fossiliferous, but they are believed to be quite recent, probably of Pliocene or later age. Under them is a limestone believed to be Miocene, and below that presumably all the older coastal plain formations in succession. There is every reason to believe that the whole swamp is underlaid by the same formations, from the Columbia down.

Immediately east of the Okefinokee is one of the most interesting topographic features of the region, which would scarcely be noticeable but for the general flatness of the country. It is a broad low ridge, exactly parallel with the coast and just about forty miles distant from it. This ridge has been traced by the writer from a few miles west of Jesup southward into the great bend of the St. Mary's River, and about thirty miles into Florida, where it is known as the "Trail Ridge," and happens to coincide in part with the Atlantic and Gulf divide and with the eastern boundary of Baker and Bradford counties, though still maintaining its parallelism with the Atlantic coast. It is not an important divide in Georgia, though no streams intersect it between the St.



ABANDONED DRAINAGE DITCH NEAR CAMP CORNELIA.

Mary's and the Altamaha except the Satilla and Little Satilla Rivers.

At Camp Cornelia, where the old drainage ditch of the Suwanee Canal Company cuts through it, this remarkable ridge is about two miles wide and only about forty feet high; and it probably keeps practically the same dimensions for many miles north and south. Its slopes are so gentle as to be scarcely noticeable to a person passing over it, but when viewed from a point a few miles away on one of the straight railroads which cross it it stands out quite conspicuously.

Interior of Jackson's Bay.

Trail Ridge, or Okefinokee Ridge, as the Georgia end of it might be called, does not belong to the class of *cuestas* or inland-facing escarpments which can be seen in many places in the upper half of the coastal plain, for it slopes equally on both sides and has no stream hugging its inland edge as far as known. Moreover, it is too smooth and too straight to have been formed by erosion. The most reasonable explanation of it would seem to be that it marks a comparatively recent slight flexure of the earth's crust, formed during one of the oscillations which the coastal plain experienced several times during its making. There seems to be a similar though smaller ridge about fifteen miles east of it, but so little is known about that that it could not be mapped at the present time. Mount Pleasant and Waynesville, near the boundary between Wayne and Glynn Counties, are located on the latter ridge, and along its summit was one of the principal roads from Savannah to East Florida a century ago, followed by Bartram and other travelers.

The internal structure of the Okefinokee Ridge is not its least interesting feature. In the big ditch at Camp Cornelia, as well as at the crossings of four railroads (three of them shown on the map and one a little farther north), there occurs beneath a few feet of white sand a chocolate-colored or almost black material of unknown depth, known locally as "hardpan." No analysis of the hardpan is available, but when pulverized in the fingers it feels like nothing but sand. Its dark color is doubtless due to vegetable matter, with a little cement of iron oxide or bog iron ore, which makes it so hard in the mass that dynamite was used in removing it, it is said. No recognizable organic remains were noticed in it, but a faint horizontal stratification could be detected. The aspect of the hardpan is so similar to that of the subsoil of existing salt marshes that its origin is not hard to guess.

JACKSON'S BAY (outer edge).

Although this peculiar formation may not be confined to the Okefinokee Ridge, its extent is evidently limited; for in railroad cuts around Waycross and Folkston and in Camden County and elsewhere the ordinary reddish Pliocene loam can be seen near the surface, without any signs of the black hardpan. The hardpan was doubtless formed in some prehistoric swamp or marsh occupying a somewhat larger area than Okefinokee does now—perhaps the "Suwannee Strait" of geologists,[6] which is supposed to have separated Florida from the mainland in Miocene times. It seems to have no effect on the vegetation above it, which is just like that of the ordinary flat pine-barrens underlaid by the loam.

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[6] See Dall, Bull. U. S. Geol. Surv., 84: 111, 121–122, 126, 1892.

Assuming the foregoing theories to be true, we can now trace the probable development of Okefinokee Swamp. When the ridge was thrown up across the shallow trough which had been Suwannee Strait it naturally created a basin behind it, which must have quickly filled with water, forming a large shallow lake. This lake then began to fill with vegetation, as many other shallow lakes and ponds in temperate regions are doing, and gradually took on the aspect it has to-day, which will be described more in detail below, under the head of vegetation. A glance at the map will show how the waters are dammed up by the ridge, the straight eastern border contrasting with the very irregular western border of the swamp.

The drainage of the region presents some peculiar features. Okefinokee Swamp is approximately on the watershed between the Atlantic Ocean and the Gulf of Mexico. In dry weather the Suwannee River seems to be its only outlet, but at other times some of the water may be discharged into the Atlantic through the St. Mary's. Being about on a watershed, the drainage area of the swamp is rather small, including only a few hundred square miles outside of the swamp itself. Its tributaries are practically confined to Ware County, on the northwest, and none of them exceed twenty miles in length. As the swamp is a few hundred feet vertically and a good many miles horizontally from any limestone, subterranean inlets and outlets are out of the question.[7] The color of the water in the swamp and in all the streams in the vicinity shows it to be entirely free from lime as well as from mud.

The courses of the Satilla and St. Mary's Rivers in the neighborhood of the swamp are rather peculiar. Each after passing through the Okefinokee Ridge turns and flows parallel to the coast for about thirty miles, in the trough between the two low ridges mentioned, and then resumes its eastward course to the sea. The circuitous channels of these rivers must have been formed at the time of the Columbia submergence of the coastal plain if not before, for in such a flat sandy country there is practically no erosion going on at the present time, and such phenomena as stream-capture are unknown.

CLIMATE

A pretty accurate estimate of the climate of the Okefinokee can be obtained by taking the averages of the figures for Waycross, Ga., and Macclenny, Fla., which lie on opposite sides of the swamp and at about the same distance from the Atlantic coast. Summed up by seasons, the average temperature and total rainfall are as follows:

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[7] Paul Fountain, in his book previously referred to, described a large limestone spring in the "northern part" of Okefinokee, but in all probability this spring was on the Suwannee River somewhere in Florida, where such things are rather common.

Seasons	Spring (March–May)	Summer (June–Aug.)	Autumn (Sept.–Nov.)	Winter (Dec.–Feb.)	Annual
Temperature (degrees Fahrenheit)............	68.4	81.6	69.3	52.3	67.9
Rainfall (inches)........	10.0	19.5	9.8	10.7	50.0

Frost usually occurs in four or five months of every year, but snow is rare. The maximum temperature here, as nearly everywhere in the eastern United States outside of the mountains, is about 100°. It is noteworthy that nearly two fifths of the total annual rainfall comes in the three summer months, as seems to be the case all over the southern half of Georgia. August is the wettest month, with about 7 inches of rain, and November the driest, with a little less than 2. The total annual amount happens to be a little less than the average for either Georgia, Florida or Alabama.

Vegetation of the Swamp

The various aspects of different parts of Okefinokee Swamp seem to depend almost entirely on the distance of the sandy bottom below or above the water level. Areas where the sand rises above the water constitute the islands. There are about half a dozen of these, Floyd's Billy's, Mitchell's, Black Jack, Honey and Bugaboo, with areas ranging from about one to ten square miles. The largest islands are naturally highest and driest, and are said to bear a fine growth of long-leaf pine (*Pinus palustris*), and perhaps some oaks and hickories. The only island which Mr. Ricker and the writer were able to reach (on account of the low stage of water prevailing at the time of our visit,

Bugaboo Island.

the rainfall that month having been only about half the normal for August) was Bugaboo Island, one of the smallest. Its surface seems to be elevated only a foot or two above the surrounding swamp, and its edges slope off so gradually that one can not tell within several rods just where swamp ends and island begins. Nine tenths or more of the trees on this island are slash pine (*Pinus Elliottii*), a species common in low or flat pine-barrens all over southeastern Georgia. The rest of the trees are mostly black pine (*Pinus serotina*), and the undergrowth consists of saw-palmettos (*Serenoa*) and several other low evergreen bushes, much as on the neighboring mainland. There is almost no grass on the island, probably on account of the rarity of fires, which outside of the swamp keep the bushes in some measure suppressed.

Sphagnum Bog with Pines and Ferns.

Bugaboo Island (and probably most of the others) is surrounded by sphagnous bogs, which resemble the northern tamarack and cedar swamps in many ways. The trees in the bogs are conifers, one evergreen, the slash pine already mentioned, and one deciduous, the cypress (*Taxodium imbricarium*); analogous to the evergreen spruce and deciduous tamarack of the northern bogs. (The white cedar or juniper, *Chamæcyparis*, the only water-loving conifer common to the glaciated region and coastal plain, is not certainly known to grow in Okefinokee, but the chances are that it grows there just as it does in Dismal Swamp and many of the swamps of Florida.) Beneath the trees, which grow rather openly, the vegetation consists of heath-like shrubs, ferns (mostly of one species, *Woodwardia Virginica*), sedges, sundews, pitcher-plants, etc. The pitcher-plants (*Sarracenia minor* and *S. psittacina*) grow two or three times as large in Okefinokee as they do anywhere else. The leaves of *S. minor,* which had never been known to grow more than a foot tall in the pine-barrens, often attain a height of over three feet in the swamp. The ground in these bogs is everywhere covered with a dense soft carpet of sphagnum.

Where the swamp muck has reached a depth of three or four feet the pines can no longer exist, and the cypress grows much more densely than it does in the bogs, constituting the bulk of the vegetation. Such places are known locally as "bays." There the long moss (*Tillandsia usneoides*) drapes every tree, though it never grows as luxuriantly as in calcareous or alluvial regions in the same latitude. The shrubs, herbs and mosses in the bays are much the same as in the bogs already described, though considerably less abundant. One shrub deserves special mention on account of its peculiar habit. It is *Pieris phillyreifolia,* a handsome little evergreen of the heath family, confined to Georgia, Florida and Alabama. It sometimes stands erect, two or three feet tall, but usually it starts at the base of a cypress tree, and its stems insinuate themselves between the inner and outer layers of the bark of the tree, gradually working upward to a height of thirty or forty feet from the ground, and sending out branches with leaves and flowers every few feet. Growing in this way the shrub might easily be taken for a parasite, but its stems can always be traced down to the ground, and they bear no rootlets and never penetrate to the living part of the bark. As far as known this manner of climbing has no parallel in the whole vegetable kingdom.

Where the sandy bottom of the swamp lies six feet or more below the average water level no trees can grow, and we have what are known as "prairies." The prairies are all in the eastern half of the swamp, where their aggregate area is perhaps as much as a hundred square miles. In wet weather the water covers them so that one can go almost anywhere in a shallow boat, especially by following the "'gator roads," or trails made by the alligators; but when the water is low the prairies are impassable for boats while still too boggy to walk in. This being the case at the time of our visit we could only view them from the banks of the canal. The bulk of the vegetation in the prairies consists of "maiden cane" (*Panicum digitarioides*),[8] interspersed with "fire-leaf" or "bull-tongue" (*Orontium aquaticum*), "wampee" or pickerel weed (*Pontederia*), white water-lilies (*Castalia*), and numerous other characteristic aquatic plants. There seems to be no sphagnum, perhaps because it will not grow without shade in that latitude. The

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[8] The true cane (*Arundinaria*), which is said to be very abundant in Dismal Swamp, seems to be entirely absent from Okefinokee, as it is from the Everglades.

prairies seem to have no counterpart in Dismal Swamp, but they look very much like some pictures of the Everglades.

The prairies are dotted here and there with small clumps of cypress trees and evergreen vines and bushes, known as "houses," from the fact that hunters sometimes camp in them while in the swamp. These probably represent shallower spots, or incipient bays.

In some of the prairies are considerable bodies of open water, known to the natives as lakes. These doubtless mark the deepest parts of the swamp, not yet filled with vegetation. They are comparatively shallow though, the combined depth of water and muck perhaps nowhere exceeding ten feet.

CHASE'S PRAIRIE.

ANIMAL LIFE

As Okefinokee Swamp has probably never been visited by a zoologist, no reliable account of its fauna can be given here. Bears and deer are still found on the islands, and occasionally stray outside of the swamp. An old hunter living at the north end of the swamp, when interviewed by a correspondent of the Atlanta *Constitution* in the spring of 1897, estimated that in the forty years he had lived there he had killed about 150 bears, 200 deer, and hundreds of wolves, minks and wildcats. In the summer of 1900 there was an item in the same paper to the effect that a large black bear had been seen at Manor, about ten miles northwest of the swamp, and caused great consternation among the negroes employed in the turpentine orchards there. Early in 1907 a bear was seen several times near Adel, in Berrien County, about sixty miles farther west, and Col. C. R. Pendleton, commenting on it in his paper, the Macon *Telegraph*, expressed the opinion that it had come out from Okefinokee by way of the swamps of the Suwannee and Withlacoochee rivers. At the time of our visit to the swamp our guide showed us on Bugaboo Island a fresh scar on a pine tree about five feet from the ground, where it had been gnawed or scratched by one of these animals. Other mammals reported from the swamp by the Constitution Expedition and Capt. Jackson, besides those already mentioned, are otters, 'coons, panthers and squirrels. In the line of birds we noticed especially a number of egrets (?), a water-turkey, and the nest of an eagle. Owls, ducks and geese were reported by the Constitution Expedition, white and blue herons and curlews were mentioned by Capt. Jackson, and Gannet Lake and Buzzard Lake, in the southern part of the swamp, probably indicate the occurrence of birds similarly named. The commonest reptiles are alligators, which sometimes attain a length of twelve feet, according to several authorities, but they are now much scarcer than formerly, owing to the depredations of hunters who seek their hides, and we saw only one live one. Snakes are not very numerous, and only one of them (a water-moccasin) was encountered in the two days we were in the swamp. "Yellow-belly terrapins" are also found there, it is said, and are sought after to some extent for their flesh. Fishes mentioned by Capt. Jackson are large-mouth black bass or "trout," weighing six to twelve pounds, and jackfish, up to ten pounds. A small specimen of the latter jumped into our boat one afternoon, and formed part of our next meal. The only insects which gave us any trouble were mosquitoes, and those only at night.

INHABITANTS

The greater part of the Okefinokee is of course unsuitable for human habitation, but the islands are known to have supported a small if not permanent population. Bartram's fanciful account of the inhabitants must have had some foundation in fact, for it is pretty well established that Indians have lived in the swamp. Billy's Island takes its name from Billy Bowlegs, a Seminole chief, who lived on it early in the nineteenth century, and there made his last stand against the whites under Gen. Floyd. On several of the islands are found low hillocks of sand, which are believed to be Indian mounds, but have apparently never been opened. The occupation of parts of the swamp by deserters during the war has already been mentioned. At the present time a large family of white people is said to be living on one of the islands near the head of the Suwannee River.

The country around the Okefinokee is rather sparsely settled. The four counties in which the swamp lies, Charlton, Pierce, Ware and Clinch, averaged in 1900 10.2 inhabitants to the square mile, 66 per cent. of whom were white. The population increased 36 per cent. between 1890 and 1900. Deducting the city of Waycross, which contains nearly half the population of Ware County, and is the largest city in the pine-barrens of Georgia, the density of population in 1900 was 8.5 per square mile, the proportion of whites 69 per cent., and the increase since 1890 30 per cent. For the whole state of Georgia the corresponding figures were 37.5 per square mile, 53 per cent. white and 21 per cent. increase.

The principal occupations of the people in these counties, outside of the towns, are stock-raising, lumbering, turpentining, farming, hunting and fishing, approximately in the order named. There seem to be a few "moonshiners" just south of the swamp in Florida. Not more than 10 per cent. of the area of the four counties named, even with the swamp excluded, has been touched by the plow as yet. Until quite recently this flat sandy land was considered as little better than a desert, but its merits are beginning to be appreciated, as is proved by the rapid increase of population in the last decade. The leading crops of this region are corn, sugar-cane, oats, sea-island cotton, sweet potatoes and rice. Sugar-cane syrup is becoming one of the principal agricultural exports, especially north and west of the swamp.

Healthfulness of the Region

Like Dismal Swamp and the Everglades, the vicinity of Okefinokee is remarkably free from climatic or endemic diseases, Fountain's statements to the contrary notwithstanding. Malaria, which in the popular mind is commonly associated with swamps of all kinds, seems to be chiefly confined to alluvial districts, and is therefore not to be expected around Okefinokee, which is strictly a non-alluvial swamp. As many as 200 men were sometimes employed in the swamp by the Suwanee Canal Company, and it is said that there was never a case of malaria among them or their families who lived at Camp Cornelia. No one is known to have ever died in the Okefinokee, from illness, snake-bite, starvation, drowning, or any other cause. On the contrary, instances are recorded of men suffering with rheumatism who have gone in there to work and come out in a few days greatly relieved, if not cured.

The chief drawback—though not a serious one—to life in the swamp is the drinking water. It is of course rather warm in summer, and always full of fine particles of peat, just as in northern cedar-swamps, but nevertheless it is not unwholesome. Its properties are doubtless similar to those of the Dismal Swamp water, which used to be preferred by navigators sailing from Norfolk and vicinity because on account of its slightly antiseptic properties it kept fresh on shipboard longer than any other kind.

The flat pine-barrens around the swamp have many attractions as a residential section, notwithstanding the pessimistic picture of them which Bradford Torrey draws in his article "In the Flat-woods."[9]

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[9] *Atlantic Monthly*, December, 1893. Also reprinted in his "Florida Sketch-book," 1894, p. 1.

Burns in 1892[10] admits the healthfulness of this kind of country while granting it no other advantage. In White's Statistics (1849) we read that there were no doctors in Wayne County at that time, because none were needed. The universal surface of sand in this region makes it the cleanest country imaginable, especially in wet weather, and also incidentally obviates the necessity of shoeing horses.

The water from shallow wells near the swamp, especially those which penetrate the "hardpan" of the ridge, is not always agreeable to persons unaccustomed to it, but an abundance of good water can be obtained from artesian wells, which are in successful operation at Waycross, Fargo, Moniac and other places.

Economic Aspects

The greatest material resource of Okefinokee Swamp to-day is of course the cypress timber. This cypress, sometimes distinguished as the pond cypress (*Taxodium imbricarium*), is not the same as the common cypress of commerce (*T. distichum*), but its wood is believed to be a little stronger and heavier if anything. The pond cypress of Okefinokee is not surpassed anywhere for quantity and size, this being near the center of distribution of this species. (The other species seems to center in the lower Mississippi valley.) With conservative methods of exploitation the supply should be practically perpetual. Next to the

Scene on Logging Canal.

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[10] Bull. 84, U. S. Geol. Surv., p. 82.

cypress the most important timber is the pine on the islands, but there is still so much of the same outside of the swamp that this comparatively inaccessible supply has not yet been drawn upon for lumber or turpentine. For the various hardwood species which inhabit the swamp there has been as yet almost no demand, and even in the easily accessible small swamps in the surrounding pine-barrens they have scarcely been touched.

The vast quantities of peat in the swamp will doubtless be useful for fuel at some future time, when coal and wood become considerably scarcer than they are now. Capt. Jackson had some of the swamp muck analyzed and found 85 per cent. of it combustible.

Doubtless the most absorbing economic question with regard to Okefinokee Swamp is whether it will be feasible to drain it. The popular demand for indiscriminate drainage of swamps will apparently never be satisfied as long as Okefinokee continues to exist. The arguments against swamp drainage in general, set forth in a recent article,[11] need not be repeated here, but a few points which apply to this swamp in particular deserve to be mentioned.

As the swamp is about 100 feet higher than the St. Mary's River at the other end of the six-mile drainage ditch, it would seem a comparatively simple matter to empty it that way, until it is recalled that the surface of the swamp slopes slightly in the other direction, and most of the water discharges into the Suwannee River. Col. Hunter estimated in 1857 that the swamp could be drained for $1,067,250, but Capt. Jackson, soon after the dredging operations of the Suwanee Canal Company began, expressed the opinion that to drain the swamp thoroughly would require over 300 miles of canals, besides a considerable deepening of the drainage ditch, which is already about 100 feet wide at the top of the ridge.

It was expected that the swamp muck when drained would make a soil of surpassing richness, but experiments made with it where it was thrown up on the banks of the canal gave only negative results. This might have been anticipated from the nature of the surrounding country, which is completely covered with quartz sand, so that the few streams emptying into the swamp carry practically no mineral matter. The sour humus of the swamp might perhaps be dug out and used to advantage on strongly calcareous soils, but there are no such soils within a convenient distance.

A sudden draining of the swamp would be disastrous in several ways. In the first place, it would kill the fish and other aquatic animals, and would probably be detrimental to the health of the surrounding country in other ways. Then it would put an end to the production of cypress timber, for which the swamp seems to be best

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[11] *Southern Woodlands*, 2: 46–67, August, 1908. See also *Science*, N. S., 28: 525, October 16, 1908; *Literary Digest*, 37: 890, December 12, 1908.

adapted. Worst of all, fire would soon get in from the surrounding pine forests (which are burned over more or less every year), and consume the muck, timber and all. Several extensive fires have already occurred in the swamp in very dry seasons, it is said, and even at the time of our visit the peaty banks of the canal were smouldering in two or three places.

With game laws properly enforced Okefinokee would be a paradise for the sportsman. Capt. Jackson wrote of it to a friend in the spring of 1892:

> There is no healthier or more attractive spot in the world, to one who can stand exposure and fatigue, than this property. If you are anything of a sportsman, I will show you fishing and hunting that has never had a parallel.

The swamp has been and still is much visited by hunters, and their wantonness has greatly decimated the large game, but none of the species have been exterminated yet, and they would probably soon reestablish themselves if given sufficient protection.

From a scenic standpoint alone Okefinokee is well worth visiting at any season of the year. Its almost untrodden islands, its dense moss-garlanded bays, and its broad open prairies, all have their peculiar charms, and must be seen to be appreciated. There is nothing else exactly like it in the world. There is really more reason for preserving Okefinokee than Niagara, for its destruction would benefit but few people in the long run, and the loss to science would be far greater. It would have been much better if this enchanting wilderness had remained in the possession of the state, to be perpetuated as a forest and game preserve for all future generations.

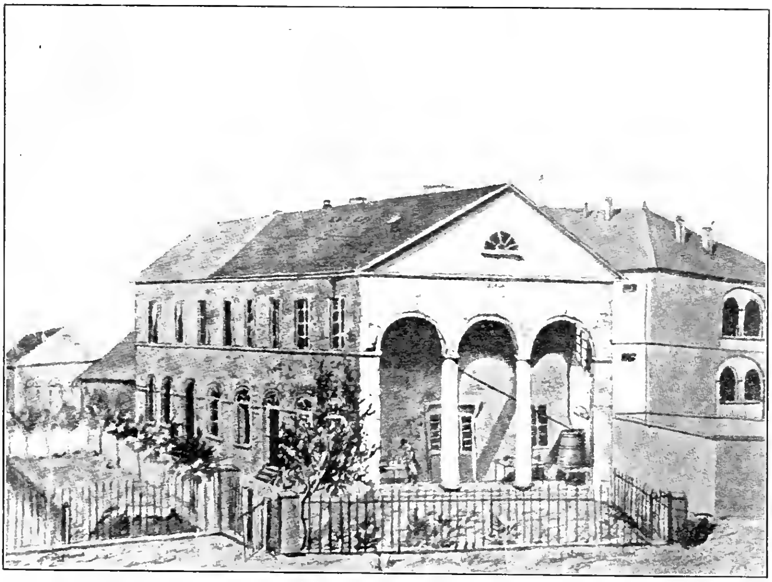
THE PROGRESS OF SCIENCE

JUSTUS VON LIEBIG AND THE FIRST LABORATORY

It has been necessary to wait a long while for a biography of Justus von Liebig, but it has now appeared from the competent hand of Professor Jakob Volhard, of Halle, a chemist of distinction, known also as the biographer of A. W. Hofmann. Liebig and Volhard's father were school friends; the young Volhard was treated almost as a child in Liebig's family; later he was his assistant at Munich and succeeded him in some of his lectures. The biography appears in two large volumes from the publishing house of Barth and contains, in addition to a full personal narrative, an extended account of Liebig's researches in organic chemistry.

As has often happened in the case of those who have become eminent in science, Liebig's father—a dealer in drugs—was engaged in work which influenced the interests of the son; his mother was a woman of character; he was backward in his school studies, but made rapid advances when permitted to take up his chosen work, so that he received his doctor's degree at the age of nineteen and an assistant professorship at the age of twenty-one; he traveled and studied abroad.

At the beginning of the last century there was in Germany a remarkable renascence in letters, philosophy and philology, to be followed a little later by the revival which gave the universities their leading place in the advancement of the natural and exact sciences. Liebig was born in 1803, and when he studied at the university the sciences were dominated by the philosophy of nature of the post-Kantians. He says that he was robbed of two precious years of his life by the infection. Schelling, whose lectures he heard, was

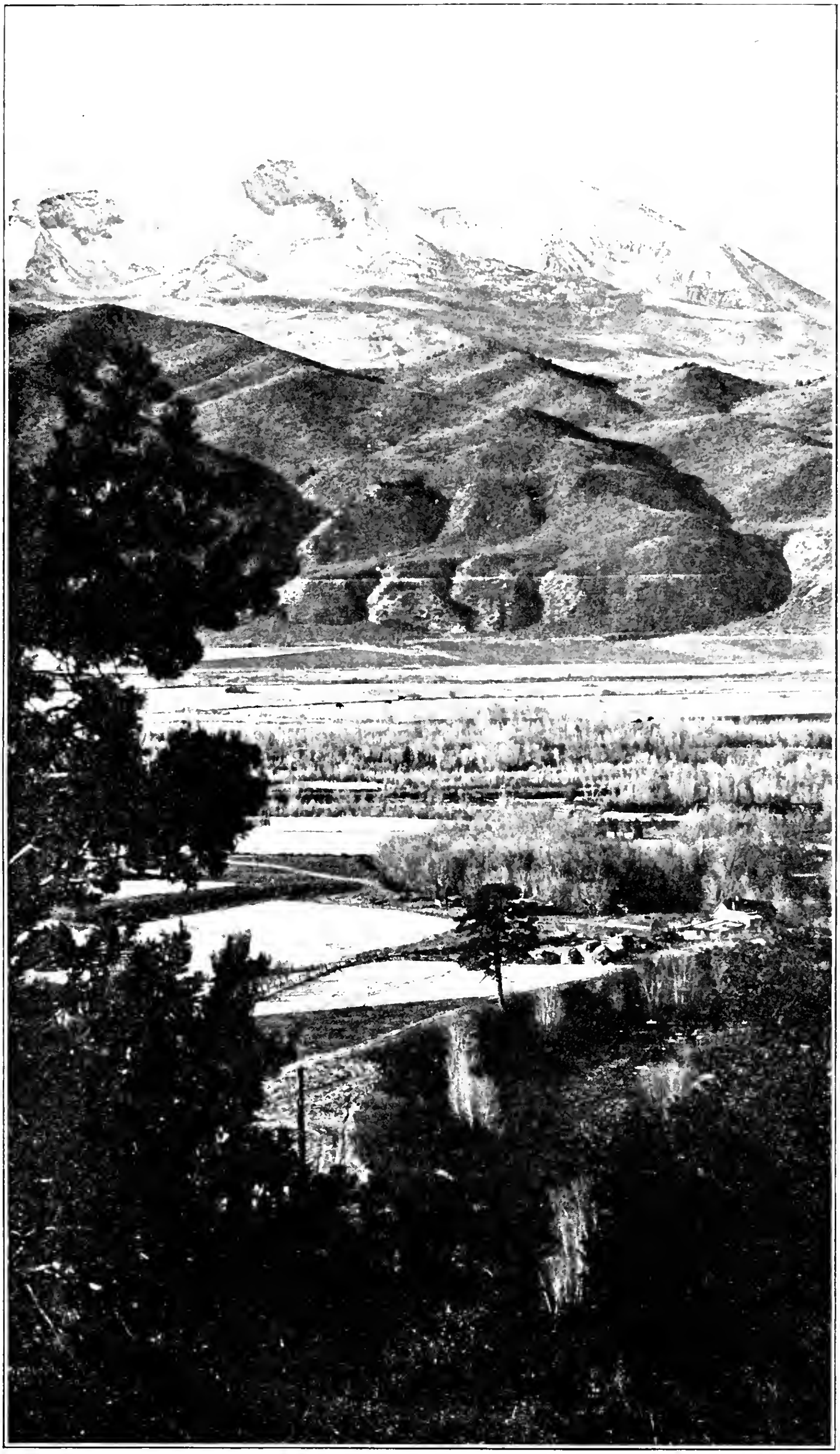


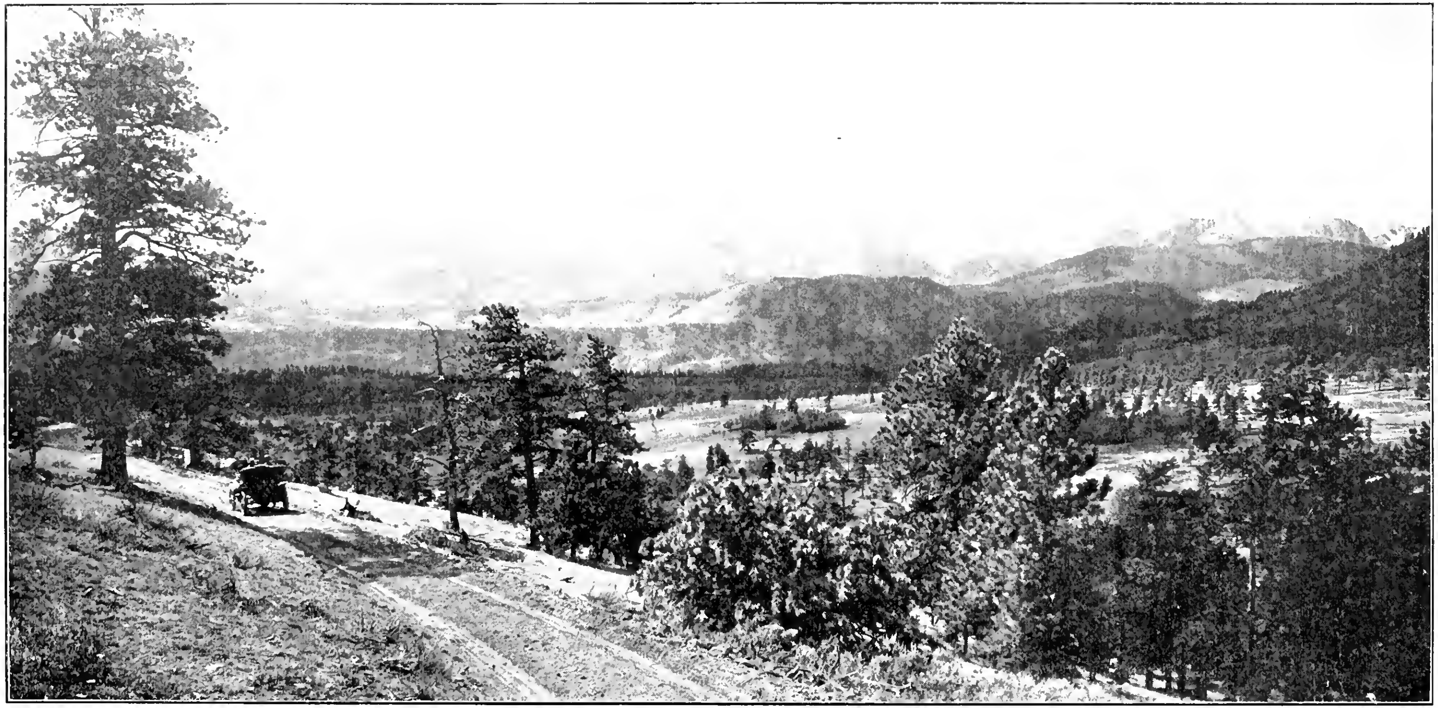
Liebig's Laboratory at Giessen.

JUSTUS VON LIEBIG.

not likely to lead a student to the study of chemistry. He was capable of writing: "The animal is in organic nature the iron; the plant is the water, for nature begins with the relative separation of the sexes, and then ends in this separation. The animal decomposes the iron, the plant decomposes the water. The female and the male sex of the plant is the carbon and nitrogen of the water." Even Kastner, the professor of chemistry whom Liebig went to Bonn to hear and followed to Erlangen, told his students that "the influence of the moon on the weather is obvious, because storms stop as soon as the moon appears."

But fortunately for science Liebig found his way to Paris and came under the influence of Gay-Lussac. In 1824 he was appointed associate professor of chemistry at Giessen and the following year opened the laboratory of chemistry which is generally regarded as the first regular scientific laboratory for research and instruction. The alchemists had their laboratories and the founders of modern chemistry had rooms in which they carried out their experiments. Anatomical laboratories





for dissection trace their history to Vesalius or even to the beginnings of the medieval university at Salernum. But Liebig's laboratory at Giessen stands for a new epoch in scientific investigation and instruction. It had its own development and was the model for chemical laboratories in other German universities and in other countries. It was some twenty-five years before similar laboratories in physics were established, to be followed still later by laboratories of zoology, physiology, botany, geology and psychology.

It is indeed a long way from "Speculative Physics"—the title which Schelling gave to his work—to the science of the modern laboratory. The transformation in the German university was truly marvelous and is due in greater degree to Liebig than to any other. It was of course a necessary evolution, but a reading of the biography of Liebig makes clear what difficulties had to be overcome and how largely this was accomplished by the energy and personality of the great chemist.

For twenty-seven years Liebig worked in the Giessen laboratory attracting students and fellow workers from all parts of Germany and from foreign countries. He there laid the foundations of organic chemistry and its applications to physiology, to agriculture and to the arts. In 1852 Liebig accepted a call to Munich. He died in 1873.

SCIENTIFIC AND EDUCATIONAL MEETINGS

The principal scientific congress of the year consists of the scientific societies meeting in affiliation with the American Association for the Advancement of Science in New Year's week, with an attendance in the neighborhood of 2,000 scientific men. The meeting next in importance should be that of the National Academy of Sciences at Washington in the third week of April. The academy has high functions as the adviser of the government in scientific matters and high traditions in maintaining the prestige of science. If, however, the academy transacts business of importance behind closed doors this does not appear in the annual reports, and the scientific programs are small and somewhat uneven in character. At the last meeting there were nineteen papers on the program not all of which were presented. Several of these were important and interesting, and several were important but not interesting to others than experts in the special subject. In general the programs are not of sufficient value to attract to Washington men of science other than members of the academy.

The American Philosophical Society, founded in Philadelphia by Franklin on the model of the Royal Society, after becoming local in character has again undertaken to hold general meetings. They follow immediately those of the National Academy and appear to have become of greater general interest. Thus at the recent meeting there were about fifty papers on the program and some of the events, such as the Darwin memorial session addressed by Ambassador Bryce, were of real significance. The society is fortunate in having its historic building on Independence Square and means to provide luncheons, dinners and receptions. It seems probable, however, that academies having a limited membership selected for eminence and programs covering all the sciences belong to the eighteenth rather than to the twentieth century.

The professional societies in the applied sciences and in education always have successful meetings. The American Medical Convention, meeting in Atlantic City early in June, and the National Educational Association, meeting in Denver early in July, are certain to bring together thousands of members. The National Educational Association not only has programs attractive to teachers, but the excursion elements are emphasized so that the trip itself is of social and educational value. Many teachers will combine attendance on the sessions at Denver with a visit to the Rocky Mountains, several views of which are here reproduced.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Frank Leo Tufts, A.B., adjunct professor of physics in Columbia University; of Dr. W. H. Edwards, known for his work on the butterflies of North America, and of the Rev. Dr. Sereno E. Bishop, who had made contributions to our knowledge of the Hawaiian volcanoes.

The following new members of the National Academy of Sciences were elected at the meeting on April 22, 1909: Professor Joseph S. Ames, Johns Hopkins University; Professor Maxime Bôcher, Harvard University; Professor Oskar Bolza, University of Chicago; Mr. Frank W. Clarke, U. S. Geological Survey; Dr. John M. Clarke, New York State Museum; Professor John M. Coulter, University of Chicago; Professor Henry Crew, Northwestern University; Professor Thomas Hunt Morgan, Columbia University; Mr. Waldemar Lindgren, U. S. Geological Survey; Professor Henry L. Wheeler, Yale University. The following were elected foreign associates: Professor Albrecht Penck, University of Berlin; Professor Gustaf Retzius, Stockholm; Professor Wilhelm Waldeyer, University of Berlin; Professor Wilhelm Wundt, University of Leipzig.

The following new members have been elected to the American Philosophical Society: Louis A. Bauer, William Howard Taft, Washington, D. C.; Marston Taylor Bogert, Hermon Carey Bumpus, Dr. Alexis Carrel, A. V. Williams Jackson, New York; Edwin Brant Frost, Williams Bay, Wis.; Robert Almer Harper, Charles Richard Van Hise, Madison, Wis.; William Herbert Hobbs, Victor Clarence Vaughan, Ann Arbor, Mich.; Abbott Lawrence Lowell, Boston; William Romaine Newbold, John Frederick Lewis, Charles Bingham Penrose, Philadelphia; Francis Darwin, Cambridge, England; Hermann Diels, Emil Fischer, Berlin; Friedrich Kohlrausch, Marburg; Wilhelm F. Ph. Pfeffer, Leipzig.

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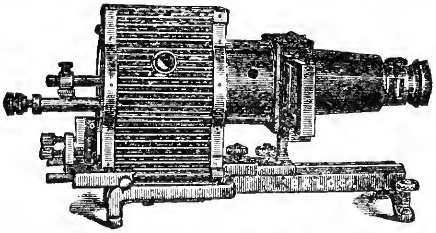

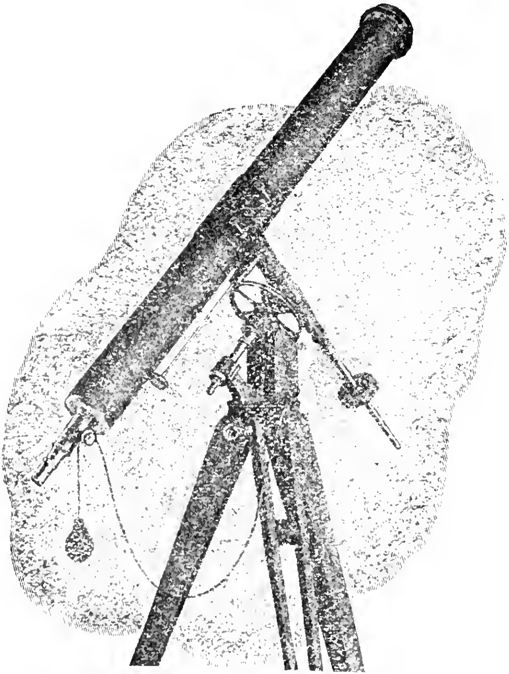

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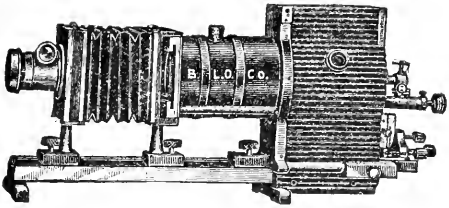
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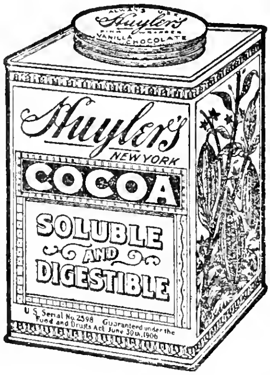
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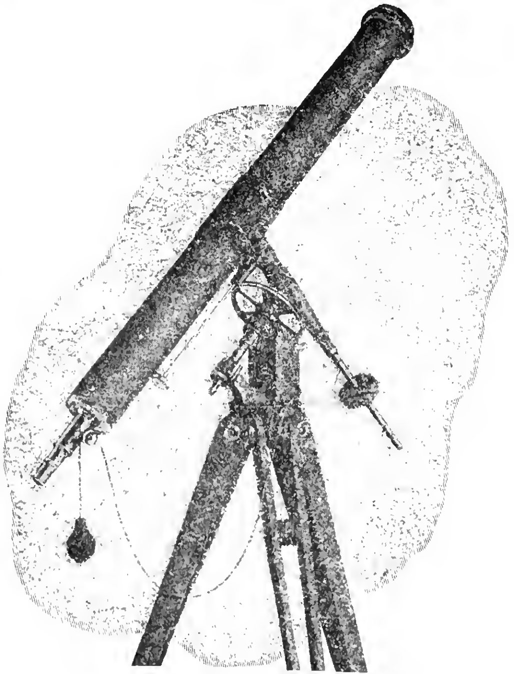

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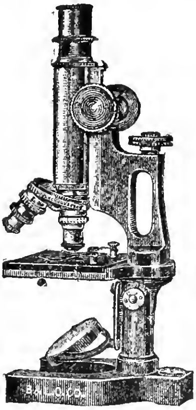

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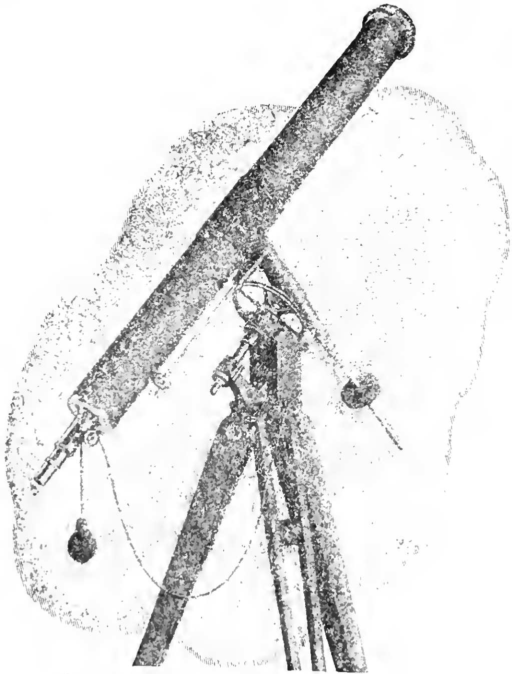

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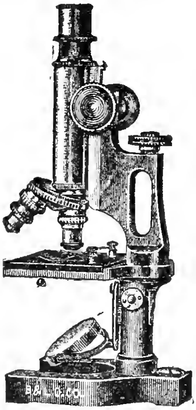

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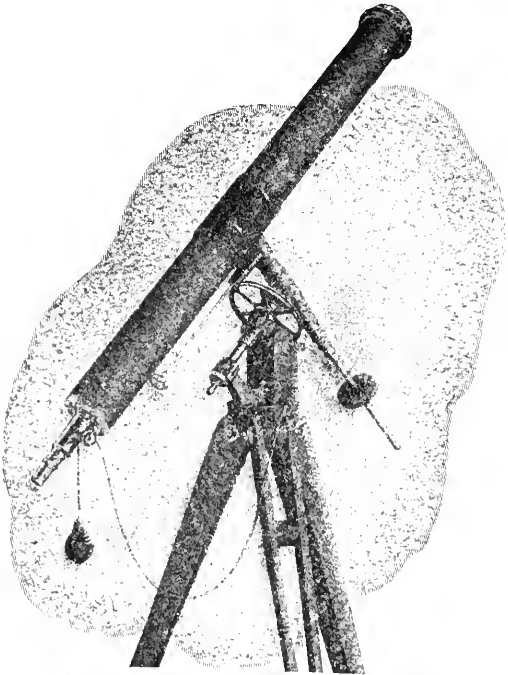

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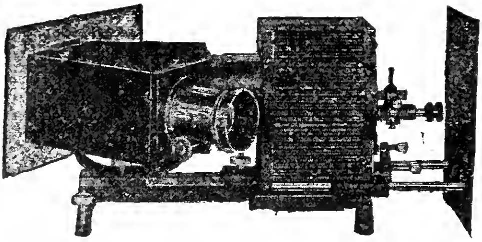

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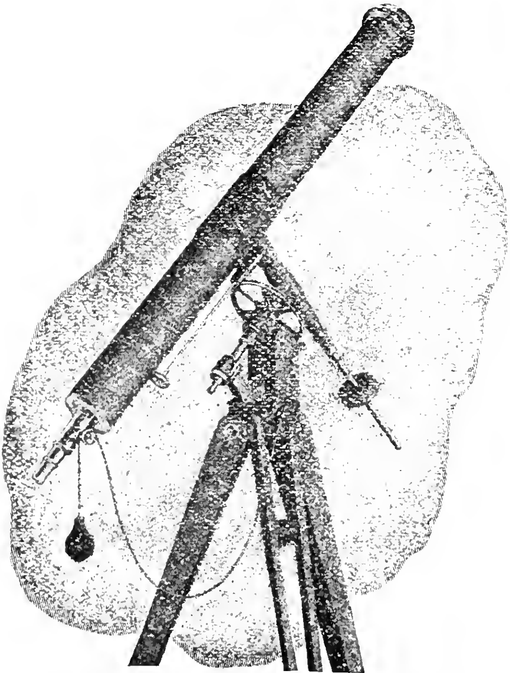

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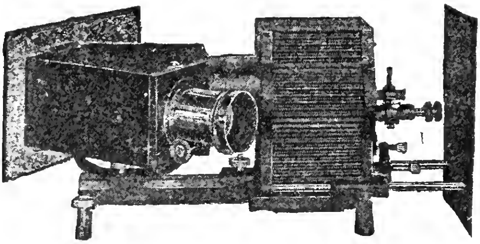

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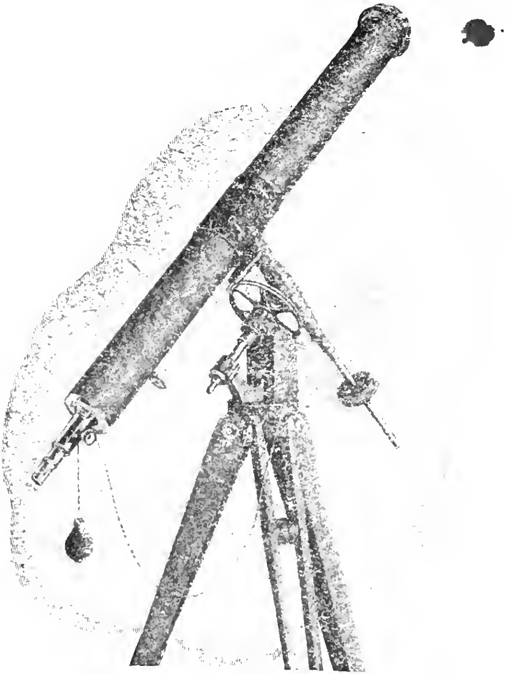

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